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Syllabus

BASIC CIVIL ENGINEERING & MECHANICS

UNIT-I :

BUILDING MATERIALS & CONSTRUCTION

Stones, bricks, cement, lime, timber-types, properties, test & uses, laboratory tests concrete and mortar Materials – Workability, Strength properties of Concrete, Nominal proportion of Concrete, preparation of concrete, compaction, curing.

Elements of Building Construction, Foundations conventional spread footings, RCC footings, brick masonry walls, plastering and pointing, floors, roofs, Doors, windows, lintels, staircases – types and their suitability.

UNIT-II :

SURVEYING & POSITIONING

Introduction to surveying Instruments – levels, theodolites, plane tables and related devices. Electronic surveying instruments etc. Measurement of distances – conventional and EDM methods, measurement of directions by different methods, measurement of elevations by different methods. Reciprocal levelling.

UNIT-III :

MAPPING & SENSING

Mapping details and contouring, Profile Cross sectioning and measurement of areas, volumes, application of measurements in quantity computations, Survey stations, Introduction of remote sensing and its applications.

UNIT-IV :

FORCES AND EQUILIBRIUM

Graphical and Analytical Treatment of Concurrent and non-concurrent Co-plannar forces, free Diagram, Force Diagram and Bow's notations, Application of Equilibrium Concepts – Analysis of plane Trusses – Method of joints, Method of Sections. Frictional force in equilibrium problems.

UNIT-V :

CENTRE OF GRAVITY AND MOMENT OF INERTIA

Centroid and Centre of Gravity, Moment of Inertia of Area and Mass, Radius of Gyration, Introduction to product of Inertia and Principle Axes, Support Reactions, Shear force and bending moment Diagram for Cantilever & simply supported beam with concentrated, distributed load and Couple.

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UNIT

1

BUILDING MATERIALS & CONSTRUCTION

STONES – TYPES, PROPERTIES, TEST & USES

Q.1. What do you understand by building material ? Give examples. *(R.G.P.V., Dec. 2015)*

Ans. All the building structures are composed of different types of materials. These materials are either called as building materials or materials of construction. Building materials account for 50 to 80 percent of the total value of construction. Thus it is important that they should available easily.

Building materials provide important role in construction of various projects like buildings, roads, bridges, tunnels, dams etc. Building materials provide better structural strength, functional efficiency and aesthetic appearance. There are various types of building materials depends upon their types, properties, uses and manufacture –

(i) Building stones and aggregates
(ii) Bricks, tiles, terra-cota, etc.
(iii) Limes and cements
(iv) Mortar and concrete
(v) Sand and surki
(vi) Timber, plywood and allied products
(vii) Plastics, P.V.C. materials and allied products
(viii) Iron, steel and alloys
(ix) Insulating materials
(x) Roof covering materials.

Q.2. What do you mean by stone ? *(R.G.P.V., Dec. 2005)*

Ans. Stones are derived from rock's earth crust. It does not have any definite shape and structure. In actual, these are the fragmented parts of the rock. These are mainly formed by weathering of sedimentary rocks by sunrays, wind and water. Sedimentary rocks are formed by the deposition of broken up materials those are weathered from primary rocks. Igneous rocks are formed by cooling of molten lava. Metamorphic rocks are formed by metamorphosis of these rocks by enormous heat and pressure.

Q.3. Write down the classification of stone. ***(R.G.P.V., Dec. 2005)***

Ans. Stones may be classified in four types –

(i) Physical classification
(ii) Geological classification
(iii) Scientific or engineering classification
(iv) Practical classification.

(i) Physical Classification – Depends upon physical classification, rocks are classified in two groups, namely stratified and unstratified.

(a) Stratified Stones – These stones are derived from sedimentary rocks. These stones are found in layers one above the another. Limestone and sandstones are the stratified stones.

(b) Unstratified Stones – These stones do not show any types of layers. Granite, marble, trap etc. are the unstratified stones.

(ii) Geological Classification – Depends upon geological formation of rocks, stones are classified as, igneous, sedimentary and metamorphic rocks.

(a) Igneous Rocks – These are formed by cooling of molten lava. Structure of stone depends upon rate of cooling of lava. This lava becomes hard on cooling and formed igneous rocks. These rocks are durable, hard, massive and stronger than other stones.

(b) Sedimentary Rocks – These are formed by deposition of sediments due to action of air and water. Due to action of high speed wind and heavy rain, igneous rocks are disintegrate and deposited in layers, on the earth crust and formed sedimentary rocks. Limestone, sandstone and slate are the sedimentary rocks.

(c) Metamorphic Rocks – These rocks are either the sedimentary rocks or the igneous rocks whose physical and chemical properties are changed due to action of high temperature and pressure. Dolomite, slate, marble, gneiss are the metamorphic rocks.

(iii) Scientific or Engineering Classification – Depends upon chemical compositions, stones are divided into three classes –

(a) Silicious Rocks – These have silica as the principal constituent. These rocks are hardly affected by weathering action. These are very hard and durable. Granite, sandstone, gneiss, basalt, trap, syenite are the silicious rocks.

(b) Argillaceous Rocks – These have clay as the principal constituent. These stones are hard and durable but brittle in nature. Slate and laterite are the argillaceous rocks.

(c) Calcarious Rocks – These have carbonate of lime as the principal constituent. Limestone, marble, kankar, dolomite and gravel are the calcarious rocks.

(iv) Practical Classification – Depends upon physical characteristics, stones are classified as under –

(a) Granite – The formation minerals of granite are quartz, felspar and mica. Its having specific gravity 2.63 to 2.75. Its having light or dark grey, pink or reddish colour. It is the most valuable stone for constructional purposes. Its having heavy weight and also durable to all other stones. Its having crushing strength of 1000 to 1400 kg/cm^2. It is very strong, heavy, hard and durable. It contains silica 60 to 80%. Its cost is much high, hence it is not readily used and also not used for ordinary building works. Mostly, granites used for ornamental works, construction of bridges, piers, sea walls etc. It is used for heavy engineering works because of its having higher crushing strength.

(b) Sandstone – Sandstones are composed of sand grains, cemented together by calcium or magnesium carbonate or silicic acid, alumina and oxide of iron. Its having specific gravity 2.25. It is white, grey, brown or red in colour. Its having crushing strength of 400 to 800 kg/cm^2.These are strong under pressure, but it is flaky when it contains mica. These are hard, non-absorbent, strong and heavy. These are easily workable and also resists the weathering in a better way. These are also used for the face work and ornamental work.

(c) Limestone – These are carbonate of lime, intermined with other minerals and impurities such as silica, magnesium carbonate, aluminium and iron. Its having yellow, brown, grey or violet colour. Its having specific gravity 2.56. Its having crushing strength 300 to 500 kg/cm^2. These are soft and absorbent and so they do not resist the weathering action well. Chalk, marbles are the examples of limestone. Granular limestone is fairly hard and not subjected to acidic actions. It is soft, light and absorbent. It is used in columns, staircases, steps, floors, dados, pilasters. It is used in blast furnace. It is used in tanning, bleaching and other industries.

(d) Slate – These are composed of silica and alumina. These are usually grey black or dark blue. Its having specific gravity 2.8. Its having crushing strength 700 to 2100 kg/cm^2.These are hard and tough and laminar in nature. It is useful for roofing as well as for flooring. These are metamorphic clay rocks. It is compact, fine grained and of uniform colour. It can be splitted in to thin slabs. It gives metallic sound when struck. It is used as a damp proof course, bathroom partitions, wall decoration, dado, steps etc.

(e) Basalt or Trap – It is a compact, dense looking heavy stone contain silica, alumina, augite, felspar and other minerals. Its having specific gravity 2.85 to 2.96. Its having dark and bluish, green, grey colour. It is very hard and difficult to work and get large blocks. It is an igneous rock. It is generally used for road metal, pavements and manufacture of artificial stone.

(f) Gravel – These are the water-born pebbles of various stones. These having small size and found in the river bed. These are used in making concrete and as road metal.

(g) Kankar – It is an impure limestone, containing about 30% of clay, sand and other impurities. These are grey in colour. These having porous structure. It is soft, light and absorbent. Big size kankar is used as a building material. Nodular kankar used as road metal for light traffic. It yields excellent hydraulic lime when burnt.

(h) Laterite – It is sandy claystone, containing high percentage of oxide of irons. Its having deep brown or red colour. It has porous and cellular structure. It has protective coating against decay, hence it is used for exterior work of building construction, culverts and road making.

(i) Murum – It is decomposed laterite. Its having deep brown or red colour. It acts as a fine blindage for roads, hence used in roadway. It is soft and fine grained.

(j) Marble – It is a compact crystalline lime stones which has been exposed to metamorphic action. Its having white, yellow, pink, red, black or green colours. Its having specific gravity 2.72. Its having crushing strength 500 to 600 kg/cm^2. It is very hard and durable. It can be easily carved. These are used for ornamental and face work of any building. It is used as floors, dados, staircases, steps and other specialized building work.

(k) Gneiss – It is the metamorphic and stratified granite. Its having black, brown and reddish colour. Its having specific gravity 2.7. Its having crushing strength 2200 to 3700 kg/cm^2. It is hard and durable. It is used as stone masonry and as aggregate for concrete. It is also used as road metal in pavements.

Q.4. What are the qualities of a good building stone ?

(R.G.P.V., June 2009)

Or

Describe the engineering properties of stones with the prescribed engineering values. ***(R.G.P.V., June 2010)***

Ans. A building stone should be hard, strong and durable to resist wear and tear due to atmospheric actions. It should free from cracks, cavities, flaws, soft materials patches, loose organic matters. It should be close-grained, compact texture and of uniform colour. The salient characteristics of good stones are explained in following heads –

(i) Appearance – It is the important factor when stones are used in the face work of large buildings. For the good appearance of the building, colour and texture of stones are of importance. The stones of light shades are always preferred. The building stone should have a pleasing and uniform colour. The stone should be free from cracks, decay, clay holes etc.

(ii) General Structure – The rocks having unstratified structure are good for the building stone. Rocks of stratified nature will split up along the plane of stratification, if not properly placed.

(iii) Fineness of Grain – Fine grained stones are suitable as the building stone, because these having good crushing strength as well as good texture. Coarse grained stones will easily disintegrate due to weathering action.

(iv) Compactness – Compact stones are suitable as the building stone, because these can resist the more pressure.

(v) Weight – Heavy weighted stones are suitable as building stones, because weight of a stone indicates the porosity and density of the stone. For structural ability heavy weighted stones are preferred. While on the other hand, for arch, vault, dome etc., light weighted stones are preferred.

(vi) Porosity – A good stone should have less porosity, because lesser the porosity, more the compactness and vice versa. More or less, almost all the stones are porous. Porous stones are easily decomposed and disintegrate. Hence less porous stone will be well suited for the building work.

(vii) Durability – A stone which is hard and strong may be durable. A good building stone must be durable. The duarability of a stone depends upon the structural formation, chemical composition, cementing material and the power of resisting wear and tear.

(viii) Strength – A good building stone must have good crushing strength. The crushing strength of stone varies from 150 to 1000 kg/cm^2.

(ix) Hardness – This is an important factor when stone is subjected to great wear and tear. A good building stone must be hard enough. Generally hard stones are used as road metal and as railway ballasts. Hardness is essential for piers, abutments and foundation stones. A rock not scratched by a knife, represents a hardness of 7 and a scratch with finger nail represents a hardness of 2.

(x) Weathering – It is the power of stones to resist the wear and tear due to atmospheric actions. Stones having poor weathering will decomposed and disintegrate easily and lastly will damaged the structure. The stone is more durable if it is capable of resisting atmospheric and other external influences.

(xi) Workability – A good bulding stone should be readily workable. These should have the qualities to facilitate easy cutting, dressing and bringing into the required shape and size.

(xii) Absorption of Water – A good building stone should not absorb the more water. More water absorption shows the porosity of the stone. A sandstone should not absorb the water more than 10 percent when immersed in water for 24 hours. Similarly, limestone should not absorb more than 17 percent of water of their volume and granite should not absorb the water more than 1 percent.

Q.5. Write down various tests performed on stones.

Or

List out engineering tests on stones and explain any two tests in detail with their standard values. ***(R.G.P.V., June 2003, Jan./Feb. 2006)***

Ans. Quality of any stone can be judged by appearance, weight, texture and stucture. But there are some tests, with the help of these tests we can know about the quality of any stone.

Following are these tests –

(i) Smith's Test – A piece of a stone chip having small size and which one is freshly quarried is kept in a glass of clean water, one third full. Stir the water for half an hour. If only slightly cloudness is present, that means stone is good and durable. If the water is too dirty, it will indicate that the stone contains too much of soluble earthy and mineral matters.

(ii) Acid Test – This test shows the power of stone to withstand atmospheric actions, gases and acid fumes. 100 gms of stone chips are kept immersed in a 5 percent solution of dilute sulphuric acid or hydrochloric acid for three days. After taking out of chippings, if the edges and corners remain sharp as they were before, it indicates that the stone is sound to resist weathering action.

(iii) Absorption Test – Keep 50 gms of stone chippings in an oven at 105° C for three days and then cool in a desiccator and takes the weight w_1 of the dry sample after being cooled in a desiccator. Now immerse the sample in distilled water for three days and takes the weight w_2 of the wet sample on taking out from distilled water. Then, absorption of water $= \dfrac{w_2 - w_1}{w_1} \times 100$

This is expressed in percentage.

(iv) Resistance to Crushing – The crushing strength of stones may be tested in a crushing testing machine. Testing blocks are usually 10 cm cubes.

Three Nos of blocks to be tested. These specimen blocks are placed in water for 72 hours, after 72 hours the specimens are taken out from water.

The surface of specimen is covered with plaster of paris the load is then applied axially on the cube in a crushing testing machine. The rate of loading is 13.72 N/mm^2 per minute. The crushing strength of the stone per unit area is the maximum load at which its sample crushes or fails divided by the area of the bearing face of the specimen.

The crushing strength of various stones vary from 150 to 1000 kg/cm^2.

(v) ***Hardness*** – Hardness of a stone is tested by scratching the stone with a knife.

(vi) ***Toughness*** – Toughness of a stone is tested by breaking the stone under a hammer. In actual, toughness is the resistance to hammering.

Q.6. Write various uses of stones in civil engineering works.
(R.G.P.V., June 2005, Dec. 2005)

Ans. Various uses of stones are as follows –

(i) Stones are used for various types of construction work like in building works for foundations, beams, columns, lintels, walls, vaults and domes.

(ii) As stones are having higher crushing strength, so that, these are used for foundation works.

(iii) Broken stones are used for roofs and flooring work.

(iv) Stones are used in roadways and called as road metal.

(v) Stones are called as railway ballast as they are used along railway track.

(vi) In ancient buildings they are used for ornamental purposes.

BRICKS – TYPES, PROPERTIES, TEST & USES

Q.7. What do you understand by term brick ?

Ans. Bricks are artificial stones those are usually made of clay. These are used in building construction and for ornamental purposes. These are one of the basic material used for wall construction. These are easily available, cheap and light weighted. They can be mould into required shape and size. The properly manufactured bricks are nearly as strong as stone.

Different types of bricks can be manufactured from different materials, such as mud bricks, refractory bricks, silica bricks, cement sand bricks, fire bricks.

Q.8. What are the ingredients of a good brick earth ? Describe the function of each ingredient. (R.G.P.V., June 2005, 2007, March/April 2010)

Ans. Following are the constituents of good brick earth –

(i) ***Alumina*** – It is the chief constituent of every kind of clay. A good brick earth should contain about 20% to 30% of alumina. This constituent imparts plasticity to the earth so that it can be moulded.

(ii) ***Silica*** – It exists in clay either as free or combined. As free sand, it is mechanically mixed with clay and in combined form, it exists in chemical composition with alumina. a good brick earth should contain about 50% to 60% of silica. The presence of this constituent prevents cracking, shrinking and warping of raw bricks. It thus imparts uniform shape to the bricks.

(iii) ***Lime*** – A small quantity of lime not exceeding 5 per cent is desirable in good brick earth. It should be present in a very finely powdered state because even small particles of the size of a pin-head cause flaking of the bricks. The lime prevents shrinkage of raw bricks. The sand alone is infusible. But it slightly fuse at kiln temperature in presence of lime. Such fused sand works as a hard cementing material for brick particles.

(iv) ***Oxide of Iron*** – A small quantity of oxide of iron to the extent of about 5 to 6 percent is desirable in good brick earth. It helps as lime to fuse sand. It also imparts red colour to the bricks.

(v) ***Magnesia*** – A small quantity of magnesia in brick earth imparts yellow tint to the bricks and decreases shrinkage. But excess of magnesia leads to the decay of bricks.

Q.9. What are the nominal and actual dimensions of modular and traditional bricks ?

Ans. Bricks are made up of different sizes, according to traditions of country and requirement of the consumer. The size of the bricks should be such, that they can be easily lifted and placed wherever required and can be burnt up to the core of the brick.

The old traditional bricks were available in the sizes of 30 cm × 15 cm × 6 cm (Indian bricks), 25 cm × 12.5 cm × 2.7 cm, (Bengal bricks) and 10 cm × 7.5 cm × 2.5 cm (Jafri bricks).

The standard sizes of the bricks are as follows –

Length (cm)	*Width (cm)*	*Height (cm)*
19	9	9
19	9	4

Or

19 cm × 9 cm × 9 cm and 19 cm × 9 cm × 4 cm

Q.10. What is frog ? Explain. ***(R.G.P.V., June 2016)***

Ans. Frog is an mark left on the face of a brick during moulding process. Frog in the brick is formed by providing a projection or a fillet on the corresponding face of mould. Frog is provided to achieve following purposes–

(i) Frog provides the key for mortar for developing a structural grip when used.

(ii) Frog indicates the name of the firm who manufacture the bricks.

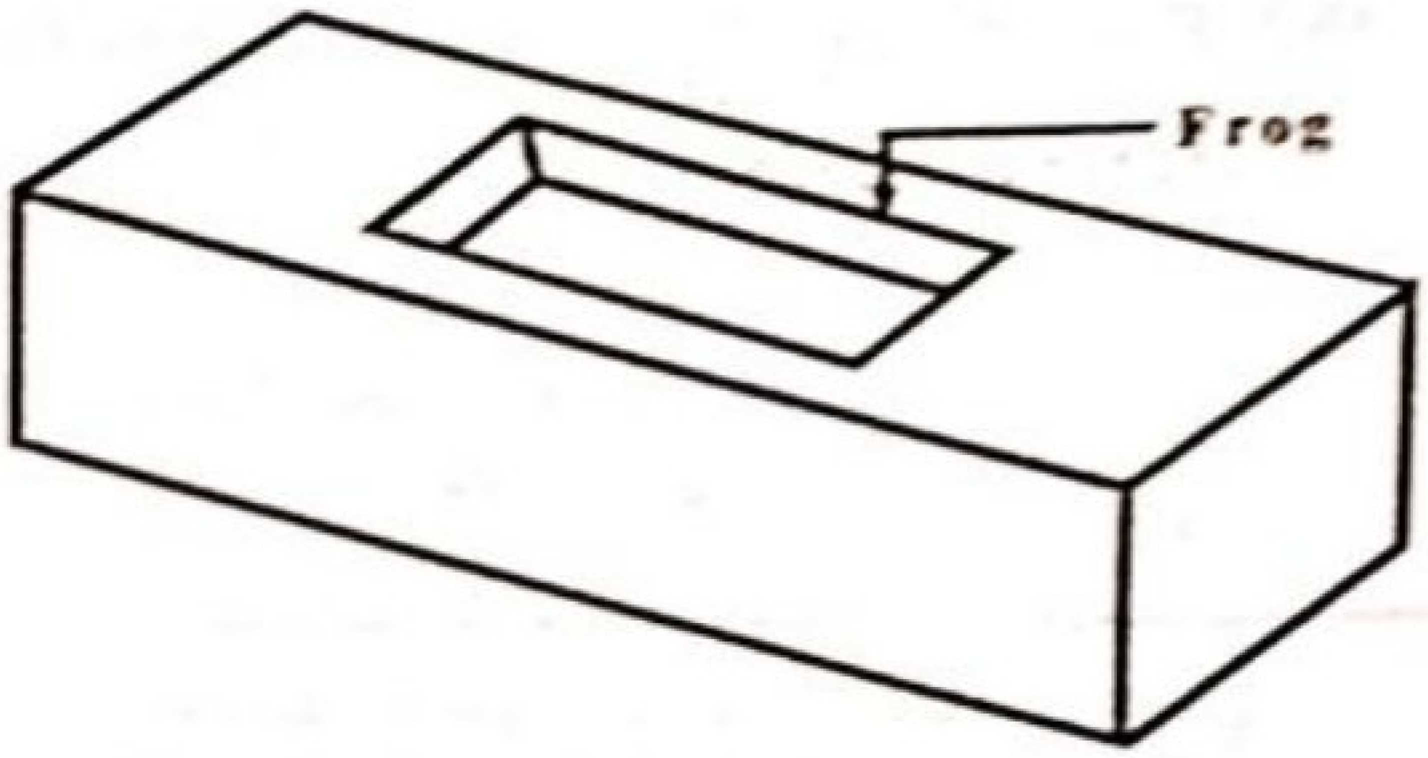


Fig. 1.1 Brick Showing Frog

Q.11. What are the merits of bricks over stones ?

[R.G.P.V., June 2008(N)]

Ans. There are following merits of bricks over stones –

(i) Bricks are cheaper than stones and easily available.

(ii) Bricks resist the various atmospheric effects in a better way than the stones.

(iii) Bricks are light in weight than stones so as they are easy for handling.

(iv) The bricks resist fire better than stones and hence, in case of a fire they do not disintegrate easily.

Q.12. Compare stone with brick, as building materials.

(R.G.P.V., Sept. 2009, Feb. 2010, Dec. 2010)

Ans. Comparison between stone and brick are given below –

S.No.	*Stone*	*Brick*
(i)	Stones are having less porosity.	Bricks are more porous than stones.
(ii)	Stones are heavy weighted.	Bricks are light in weight than stones.
(iii)	They are having higher crushing strength up to 150 to 1000 kg/cm^2.	They are having lesser crushing strength than stones and up to 105 kg/cm^2.
(iv)	Stones are much durable than bricks.	They are less durable than stones.
(v)	They should not absorb water more than 10% of its dryweight when kept immersed for 24 hours.	They should not absorb water more than 20% of its dry weight when kept immersed for 24 hours.
(vi)	They are mainly used for foundation work.	They are mainly used for masonary work or wall construction.
(vii)	Stones are having less resistance against fire than bricks.	Bricks resist fire better than stones.
(viii)	Stones are costly and not available easily.	Bricks are cheaper than stones and easily available.

(ix)	Stones are used for various types of construction work like building works for foundations, beams, columns, lintels, etc.	Bricks are used in construction work for sewers, roads, lining and pitching works.
(x)	Broken stones are used for roofs and flooring work.	Broken bricks ballast is used for preparation of sub-base, subgrade of road and flooring.

Q.13. Write down the classification of bricks. (R.G.P.V., Jan./Feb. 2008)

Ans. Clay bricks are divided into ordinary and fire bricks. Ordinary bricks are classified as under –

(i) First Class Bricks – These are of proper, rectangular shape and size with sharp edges. These bricks are well-burnt and free from cracks and defects. It does not absorb water more than one-sixth of its weight kept immersed for 16 hours. No mark can be made on it with finger nails. This should produce well ringing sound when struck with each other. This should not break into pieces when dropped on ground from a height of 1 m. It should have uniform compact texture. The colour of brick should be uniform and light.

(ii) Second Class Bricks – These bricks are irregular in shape and size with spots on the surface. These have qualities almost same as those of first class bricks. They may have fine hair cracks.

(iii) Third Class Bricks – These are soft and light in colour. These are called 'Ama bricks'. These are under-burnt bricks. They produce a dull sound when struck with each other.

(iv) Zhama Bricks – These are bricks of deformed shape and size. These are over burnt bricks. During the burning process, if temperature is not under control then the bricks melt and formed irregular shape and size.

Q.14. Describe briefly the characteristics of good bricks.
(R.G.P.V., June 2001, Dec. 2002, June 2007)

Or

What are the good qualities of first class bricks ? (R.G.P.V., June 2015)

Or

Define and explain various engineering properties of good bricks.
(R.G.P.V., Dec. 2017)

Ans. There are various characteristics of good bricks –

(i) A good brick should have uniform deep red, cherry or copper colour.

(ii) It should have even surfaces, sharp edges and compact structure.

(iii) It should have fine, compact and uniform texture and should be uniform in shape and size.

(iv) It should be table-moulded, well burnt in kilns, free from cracks, flaws, loose material, nodules of free lime and any other defect.

(v) Crushing strength of brick should be 105 kg/cm^2.

(vi) The brick should be moulded from a good brick earth, which is free from vegetable matter, stones, saltpetre, harmful salts, acids and other organic matters as well as from fumes and oxides of irons.

(vii) It should be so hard that finger nails should not be able to make any impression on its surface, when scratched.

(viii) When two first class bricks are struck with each other, metallic ringing sound should be emitted.

(ix) A good brick should not absorb more than 20% water of its dry weight when kept immersed for 24 hours.

(x) Good bricks should be of standard size.

(xi) Good bricks should be able to resist atmospheric actions.

Q.15. What do you understand by lab test ?

Ans. The objective of lab test is to determine the inherent biopotency of the technical material or, in the case of formulated larvicides, their activity. It is assumed that the compound's mode of action has already been established. Information on the speed of activity is important, as this will determine the type of testing procedures to be employed.

The aims of lab test are as follow –

(i) To determine the lethal concentration.

(ii) To establish a diagnostic concentration for monitoring susceptibility.

(iii) To assess cross-resistance.

Q.16. Discuss various lab tests applied on bricks to judge the quality of bricks.

Or

What are the tests performed to check the quality of bricks ? Briefly describe any one. ***(R.G.P.V., June 2002, 2009, 2010)***

Ans. There are three basic tests, those are carried out for bricks –

(i) Compressive strength test

(ii) Water absorption test

(iii) Efflorescence test.

(i) Compressive Strength Test – Compressive strength of bricks is the load bearing capacity before it ruptures, when subjected to compressive stress. Hard and well burnt bricks have more compressive strength than the porous bricks. The crushing strength is the important factor for bricks, because it decides the suitability of brick for different uses. The crushing strength of brick can be findout with the help of crushing testing machine. Brick is fixe to the crushing testing machine and then compressive force is appied to th brick during testing operation. The crushing strength of brick should b minimum 105 kg/cm^2.

(ii) ***Water Absorption Test*** – It is the percentage of water absorbe by the dry brick to its weight. A brick is taken and it is weighed dry. It is then immersed in water for a period of 24 hours. It is weighed again, the differenc in weight indicates the amount of water absorbed by the brick. Bricks used i construction work should not absorb the water more than 20% of its dr weight. If any brick absorb the more water that means it will loose its crushin strength and will produced effect of efflorescence.

(iii) ***Efflorescence Test*** – If any brick absorb the water more tha 20% of its dry weight, along its pores by capillary action and carries with dissolved salts. The solution having white colour will evaporates from bric work and deposited on the surface. These white deposits of salts are called efflorescence. This test of the brick is necessary because if salts are presen in abundant on the surface then it will damage the bricks as well as the maso and will give ugly appearance to the building.

Q.17. Write short note on efflorescence. ***(R.G.P.V., Dec. 201***

Ans. Refer Q.16 (iii).

Q.18. What do you mean by field test ?

Ans. A field test (as defined by the National Council on Measurement Education) is a test administration used during the test development proce to check on the quality and appropriateness of test items, administrati procedures, scoring, and/or reporting.

Q.19. What are the various field tests applied on bricks to judge th quality of bricks ? ***(R.G.P.V., Dec. 201***

Or

Describe briefly the tests to which bricks may be put before using the for engineering purposes. ***(R.G.P.V., Dec. 2013***

Or

How will you judge a good brick ? ***(R.G.P.V., Jan./Feb. 2007***

Or

What are the various field tests carried out for bricks ?
(R.G.P.V., Dec. 2014

Or

Enumerate and describe the tests which may be performed in field to assess the quality of bricks. ***(R.G.P.V., June 2014***

Ans. There are various field tests those may be carried out to determine the quality of the brick –

(i) Uniformity in size (ii) Uniformity in colour (iii) Hardness
(iv) Soundness (v) Strength test.

(i) Uniformity in Size – The brick should be uniform in size and shape and should have rectangular plane surfaces with parallel sides and sharp straight right angled edges. The uniformity in size can be checked out by observing the brick on the field.

(ii) Uniformity in Colour – The brick should have uniform deep red, cherry or copper colour, which can be judged by observing the brick on the field.

(iii) Hardness – Hardness of a good brick can be tested by making a scratch on brick surface with the help of finger nail on the field. If no impression is left on the surface, brick is treated to be sufficiently hard.

(iv) Soundness – In this test, two bricks are taken and they are strucked with each other on the field. For a good brick a clear ringing sound should be produced.

(v) Strength Test – In this test, brick should not break, when dropped flat on hard ground, from a height of about one metre.

Q.20. What do you understand by lab test and field test ? Describe various field tests applied on bricks to judge the quality of bricks.
(R.G.P.V., June 2013)

Ans. Refer Q.15, Q.18 and Q.19.

Q.21. Describe about the various field tests performed to access the quality of bricks. Also discuss about the classification of the bricks.
(R.G.P.V., Dec. 2011)

Ans. Refer Q.19 and Q.13.

Q.22. Explain various types of tests that can be conducted on bricks.
(R.G.P.V., Dec. 2016)

Ans. Refer Q.16 and Q.19.

Q.23. Describe briefly the characteristics of good brick and stone. Also give the test recommended. ***(R.G.P.V., June 2011)***

Ans. Refer Q.14, Q.4, Q.16, Q.19 and Q.5.

Q.24. What are the different uses of bricks ?

Ans. There are various uses of bricks –

(i) First and second class bricks are used in construction work of buildings, dams, bridges, piers and abutments.

(ii) First class bricks are used in sewers, roads, tunnels, lining and pitching work of water structures.

(iii) Broken bricks ballast is used for preparation of sub-base subgrade of road and flooring.

(iv) They are used in reinforced brick concrete (R.B.C.).

(v) They are used in construction of arches and lintels.

CEMENT, LIME – TYPES, PROPERTIES, TEST AND USES

Q.25. What do you understand by term cement ?

Ans. Cement is an binding material which used in construction industry. Cement sets well under water and hardens quickly and attains strength. Cement differ from lime by the property that it does not slake but sets readily. Cement possesses hydraulic properties to a great extent and acquires more strength on setting. The setting power of cement is more than that of lime. In actual, cement is an calcarious substance which is used in mortar or concrete for construction.

Q.26. Describe various types of cements used in construction along with their engineering properties. ***(R.G.P.V., Dec. 2005, 2008)***

Or

Explain the different types of cement. ***(R.G.P.V., Dec. 2016)***

Ans. There are various types of cements those are classified against specific order and the relavent Indian Standard –

(i) Ordinary Portland Cement – It is the most common cement used in the construction industry. It has a low resistance to chemical attack and it has a medium rate of hardening. Chemical constituents of ordinary portland cement are lime, silica, alumina, iron oxide, magnesia, sulphur trioxide, soda and potash. Out of the total production of cement ordinary portland cement accounts for about 80 to 90 per cent. The colour of ordinary portland cement is grey or greenish grey. It has rate of strength development and rate of evolution of heat of hydration are medium. It has medium cracking resistance.

(ii) Rapid Hardening Cement – This cement is similar to ordinary portland cement. It develops strength rapidly so as it is called as high early strength cement. It develops at the age of three days, the same strength as that is expected of ordinary portland cement at seven days. The rapid rate of development of strength is due to the higher fineness of grinding and higher C_3S and lower C_2S content. A higher fineness of cement particles gives greater surface area for action of water and higher C_3S results in quicker hydration. It is used for construction of important structures and under water works. This cement contains high percentage of cement. The lighter weight of rapid hardening cement and the shorter period of water curing make its use economical compared with the normal setting cement.

(iii) Quick Setting Cement – This cement sets very early. This property is brought out by reducing the gypsum content at the time of clinker grinding. This cement is required to be mixed, placed and compacted very early. It is mostly used in under water construction. It is also useful for the purpose of grouting.

(iv) Low Heat Cement – The hydration of cement is an exothermic action which produces large quantity of heat during hydration. This heat of hydration results in cracks in large body of concrete. So technologist produced a cement, which produces less amount of heat at a low rate during the process of hydration. This type of cement is evolved by reducing the contents of C_3S and C_3A which are the compounds evolving the maximum heat of hydration and increasing C_2S.

(v) Portland Pozzolana Cement – This cement is specially useful in marine and under-water constructions. Pozzolana is the name given to volcanic ashes which is chiefly a siliceous material. Pozzolana cement is prepared by mixing and grinding clinkers and pozzolana together. Pozzolana, present in cement, reacts with the free lime liberated during hydration of cement and prevents disruption in concrete. The pozzolana constituent shall not be less than 10 per cent and not more than 25 per cent by weight of portland pozzolana cement. Portland pozzolana cement produces less heat of hydration and offers greater resistance to the attack of water than ordinary portland cement.

Q.27. What is white cement ? How is it manufactured ?
(R.G.P.V., Dec. 2014)

Ans. White cement is just a variety of ordinary cement. It is white in colour and is used for plaster work, ornamental work, floor finish etc. It should not set earlier than 30 minutes.

White cement is manufactured in such a way that the percentage of iron oxide is limited to less 1%. To achieve this, superior raw materials such as white clay (china clay) and chalk and lime stone having low percentage of iron are used. In the absence of iron oxide, sodium aluminium fluoride (cryolite) is added to act as flux. Oil fuel is used in place of pulverised coal, in the kilning process in order to avoid contamination by coal ash.

Q.28. What are the various properties of cement ? Explain it with salient points. ***(R.G.P.V., June 2016)***

Ans. The cement to be used in construction must have certain given qualities in order to play its part effectively in a structure. When these properties lie within a certain range, the engineer is confident that in most of the cases the cement performance will be satisfactory.

(i) Fineness –

(a) Fineness, or particle size of portland cement affects hydration rate, which is responsible for the rate of strength gain. The smaller the particle size, the greater the surface area-to-volume ratio, which means more area available for water-cement interaction per unit volume. The effects of greater fineness on strength are generally seen during the first seven days.

(b) When the cement particles are coarser, hydration starts on the surface of the particles. So the coarser particles may not be completely hydrated. This cause low durability and low strength.

(c) High fineness is necessary for a rapid development of strength.

(ii) Setting Time – When cement paste sets plastic state to hardened state, this time is known as setting time. The setting time is divided into two parts – first is initial setting time and second is final setting time. Initial setting time occurs when the paste begins to stiffen considerably and final setting time occurs when the cement has hardened to the point at which it can sustain some load. Setting is mainly caused by C_3A and C_3S and results in temperature rise in the cement paste.

Generally cement paste setting time is affected by a number of items including cement fineness, water-cement ratio, chemical content (especially gypsum content) and admixtures. For construction purposes, the initial set must not be too soon and the final set must not be too late.

(iii) Soundness – Soundness refers to the ability of a hardened cement paste to retain its volume after setting without delayed expansion. This expansion is due to the excessive amounts of free lime (CaO) or magnesia (MgO). Most portland cement specifications limit magnesia content and expansion. The cement paste should not undergo large changes in volume after it has set. However, when excessive amounts of free CaO or MgO are present in the cement, these oxides can slowly hydrate and cause expansion of the hardened cement paste. In other words, soundness is defined as the volume stability of the cement paste.

(iv) Compressive Strength – It is one of the important properties of cement. Strength tests are not made on neat cement paste because of difficulties in obtaining good specimens and in testing with a consequent large variability of test results. Cement-sand mortar or concrete of prescribed proportions, made with specified materials under strictly controlled conditions, are used for the purpose of determining the strength of cement.

(v) Standard Sand – The standard sand has the following properties –

(a) The standard sand shall be of quartz, of light grey or whitish variety and shall be free from silt.

(b) The sand grains shall be angular with shape approximating to spherical forms.

(c) It shall be free from organic impurities.

(d) The sand shall pass through IS : 850 µm sieve and not more than 10 percent shall pass through IS : 600 µm sieve.

(vi) Heat of Hydration – Whenever an amount of water is added to cement, it liberates considerable amount of heat. This liberation of heat is called heat of hydration. The study and control of heat of hydration is important for the construction of concrete dams and other mass concrete constructions. Heat of hydration is measured in calories per gram or joule's per gram. Heat of hydration depends upon the chemical composition of the cement. For ordinary portland cement, the heat of hydration is of the order of 120 cal/gm or 500 joules per gram. About 50% of the total heat is liberated between 1 and 3 days, about 75% in 7 days and 83 to 91% in six months. Table 1.1 shows the typical values of the heat of hydration of pure compounds.

Table 1.1

Compounds	***Heat of Hydration***	
	J/g	***Cal/g***
C_3S	302	120
C_2S	260	62
C_3A	867	207
C_4AF	419	100

It is estimated that about 120 calories of heat is generated in the hydration of 1 gm of cement. Concrete is a poor conductor of heat and it acts as an insulator. Hydration results in a large rise in temperature in the interior of mass concrete. Exterior of mass concrete loses heat. This establishes a steep temperature gradient. During subsequent cooling, micro-cracking of interior takes place which leads to loss in durability of hardened concrete mass.

(vii) Specific Gravity – The specific gravity of cement is generally about 3.15, but that of cement manufactured from materials other than limestone and clay, the value may vary. It is used in calculation of mix proportion. In short, the cement should feel smooth when touched or rubbed in between fingers. If it is felt rough, it indicates adulteration with sand. If hand is inserted in a bag or heap of cement, it should feel cool. If a small quantity of cement is thrown in a bucket of water, it should sink and should not float on the surface. A thin paste of cement with water should feel sticky between the fingers. If the cement contains too much of pounded clay and silt as an adulterant, the paste will give an earthy smell.

(a) It gives strength to the masonry.
(b) It is an excellent binding material.
(c) It is easily workable.
(d) It offers good resistance to the moisture.
(e) It possesses a good plasticity.
(f) It stiffens or hardens early.

(viii) Hydration of Cement – When cement compounds are mixed with water, they react with each other and formed hydrated compounds, this reaction is known as hydration of cement. It is exothermic reaction and liberates a considerable amount of heat. Different compounds hydrate at different rates and liberate different quantities of heat. Fig. 1.2 shows the rate of hydration of pure compounds. Since retarders are added to control the flash setting properties of C_3A. The early heat of hydration is produced due to the hydration of C_3S. The total quantity of heat generated is depends upon the quantities of major compounds present in cement.

The hydration process is not an instantaneous one. The reaction is faster in early period and ultimately slow down continuously with time. The complete hydration takes the period of one year or more. After 28 days of curing, the cement grains are hydrated to a depth of only 4μ. Generally C_2S crystals those are present in the surface of a cement grain are hydrated and the more reactive compound like C_3S lying in the interior of a cement grain does not hydrated. The hydrated product of the cement compound in a grain of cement adheres firmly to the unhydrated core in a grains of cement. So as unhydrated cement left in a grain of cement will not reduce the strength of cement mortar or cement concrete.

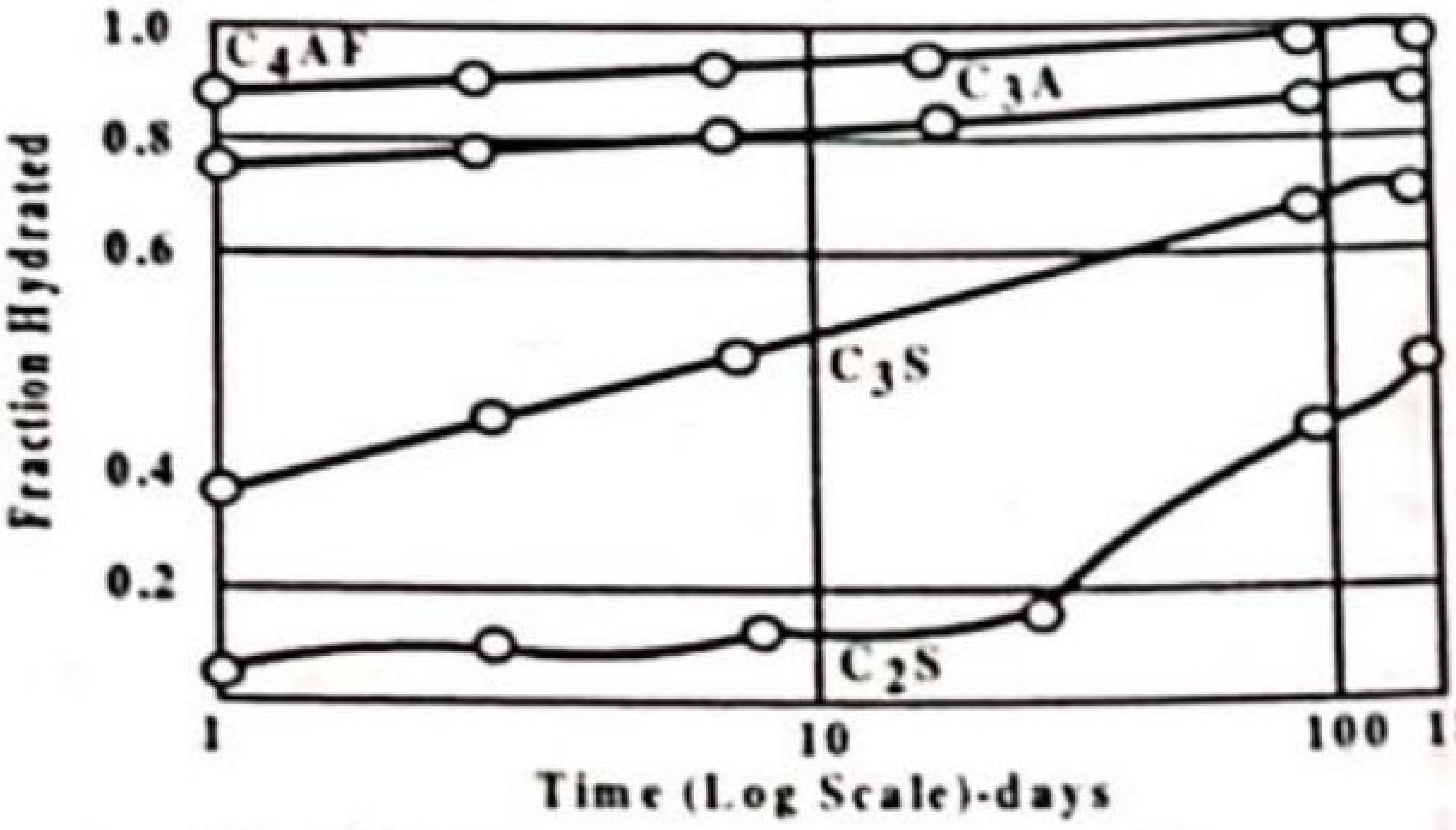


Fig. 1.2 Rate of Hydration of Pure Compounds

(ix) Water Requirement for Hydration – C_3S crystals require 24% of water by weight of cement and C_2S requires 21% of water by weight o cement. Hence an average 23% of water by weight of cement required fo chemical reaction with portland cement compounds and is called as boun water. A certain amount of water is required to fill up the gel-pores and henc this water is called as gel water. Hence an additional water about 15% b weight of cement is required to fill up the gel-pores. Therefore, a total 38% c ater by weight of cement is required for the chemical reactions and to occupy e space within gel-pores.

Q.29. What are the various laboratory tests for cement ?

Or

Mention any one test to assess quality of the cement.

(R.G.P.V., June 2010)

Or

How the quality of cement can be accessed ? Explain in brief regarding he laboratory and field tests performed on the cement.

(R.G.P.V., June 2012)

Ans. Because of the fact that cement is used in construction of various major works, it is necessary to test the cement to confirm the requirements of Indian standards with respect to its physical and chemical properties. So as to confirm these properties the following tests are usually conducted in the laboratory –

(i) Fineness test
(ii) Setting time test
(iii) Strength test
(iv) Soundness test.

(i) Fineness Test – The fineness of cement imparts impact on hydration and also on the rate of gain of strengths. Finer cement offers greater surface area for hydration and hence the faster and greater development of strength. The disadvantage of fine grinding is that it is susceptible to air-set and early deterioration The average size of the cement particles should be 10 microns. The smallest size of the particle should not less than 1.5 micron. The fineness test consist of sieve analysis. Firstly taken 100 gm of cement and sieve that sample of cement through I.S. sieve number 9 for fifteen minutes. Now weigh the residue after sieving. This should not exceed 10 percent by weight of cement.

(ii) Setting Time Test – The setting time of the cement divided as the initial setting time and final setting time. Initial setting time is the time taken during the operation as the water is added to the cement and when the paste starts losing its plasticity. Final setting time is the time taken during the operation as the water is added to the cement and when the paste lost its plasticity completely. Generally for the ordinary portland cement, initial setting time is 30 minute and final setting time is taken as 10 hours.

For finding out the initial setting time and final setting time a standard consistency test is carried out. Prepare a test block of cement of standard consistency. Fill the cylindrical mould having size 40 mm depth and 80 mm diameter completely and smoothen the surface of the paste and level it, as shown in fig. 1.3.

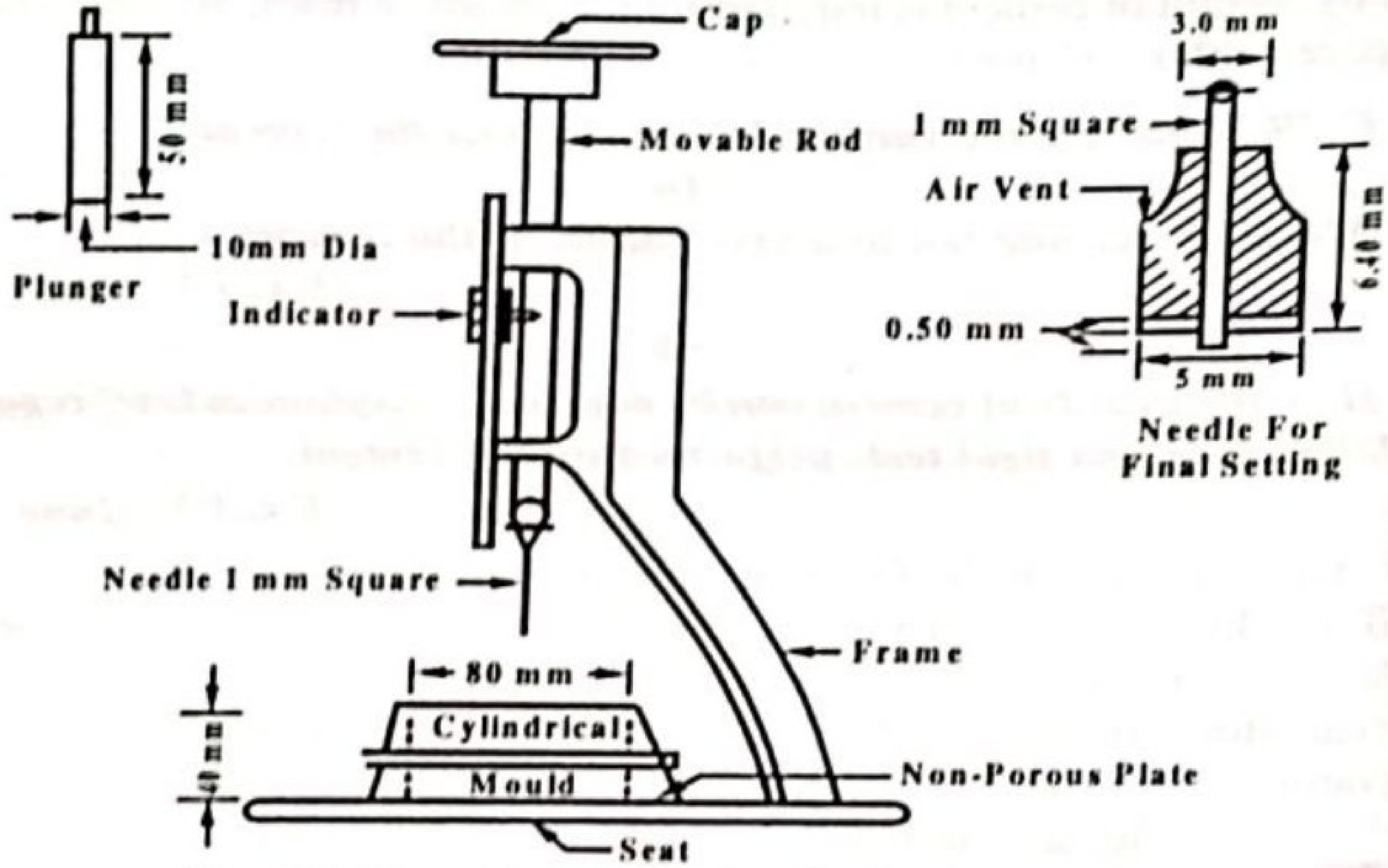


Fig. 1.3 Vicat Apparatus for Setting Time Test

(a) Determination of Initial Setting Time – Place the te block on the nonporous plate under the rod bearing needle. Lower the need in contact with the surface of the test block and quickly release, allowing it t penetrate in to the test block. In the beginning, the needle will complete pierce into the test block. But after sometime when the paste starts losing i plasticity, the needle may penetrate only to a depth of 33-35 mm from the to The period elapsing between the time when water is added to the cement an the time at which the needle penetrates the test block to a depth equal to 33-3 mm from the top is taken as initial setting time.

(b) Determination of Final Setting Time – Replace the need of the vicat apparatus by a circular attatchment as shown in figure and perfor the test as for initial setting time. The cement is considered as finally set whe the paste has attained such hardness that the centre needle does not pier through the paste more than 0.5 mm.

(iii) Strength Test – The compressive strength of hardened cement the more important property of the cement that should always checked befo used in construction works. Strength test does not made on only cement pas because of difficulties of shrinkage and cracking of only cement paste. So sand and cement are mixed in proportions and such testing is done. A ratio cement and standard sand is taken as 1:3. Then water is mixed in that and mix for 3 to 4 minutes. Immediately after mixing, the mortar is filled into a cu mould. Keep that cube mould at a temperature of 27° ± 2° C for 24 hours.

Three cubes are tested for compressive strength at different periods in rushing testing machine. The compressive strength should be average of he strength of the three cubes. The period in case of ordinary portland ement are 3 and 7 days. The compressive strength for ordinary portland ement should not less than 160 kg/cm^2 for 3 days and 220 kg/cm^2 for 7 ays.

(iv) Soundness Test – Certain cements shows expansion after setting nd cause disruption of hardened mass. The testing of soundness of cement is o ensure that the cement does not show any appreciable expansion after etting. Unsoundness of cement is due to excess of lime, magnesia and roportion of sulphates. There is Le chatelier test to findout the soundness of ement. The apparatus is shown in fig. 1.4. It consists of a small split cylinder f spring brass or other suitable metal of 0.5 mm thickness forming a mould 0 mm internal diameter and 30 mm high. On either side of the split, two ndicators are braced Suitable with pointed ends made of 2 mm diameter brass vire AA, such that the distance of these ends to the centre of the cylinder is 165 mm. The split cylinder is kept between two glass plates.

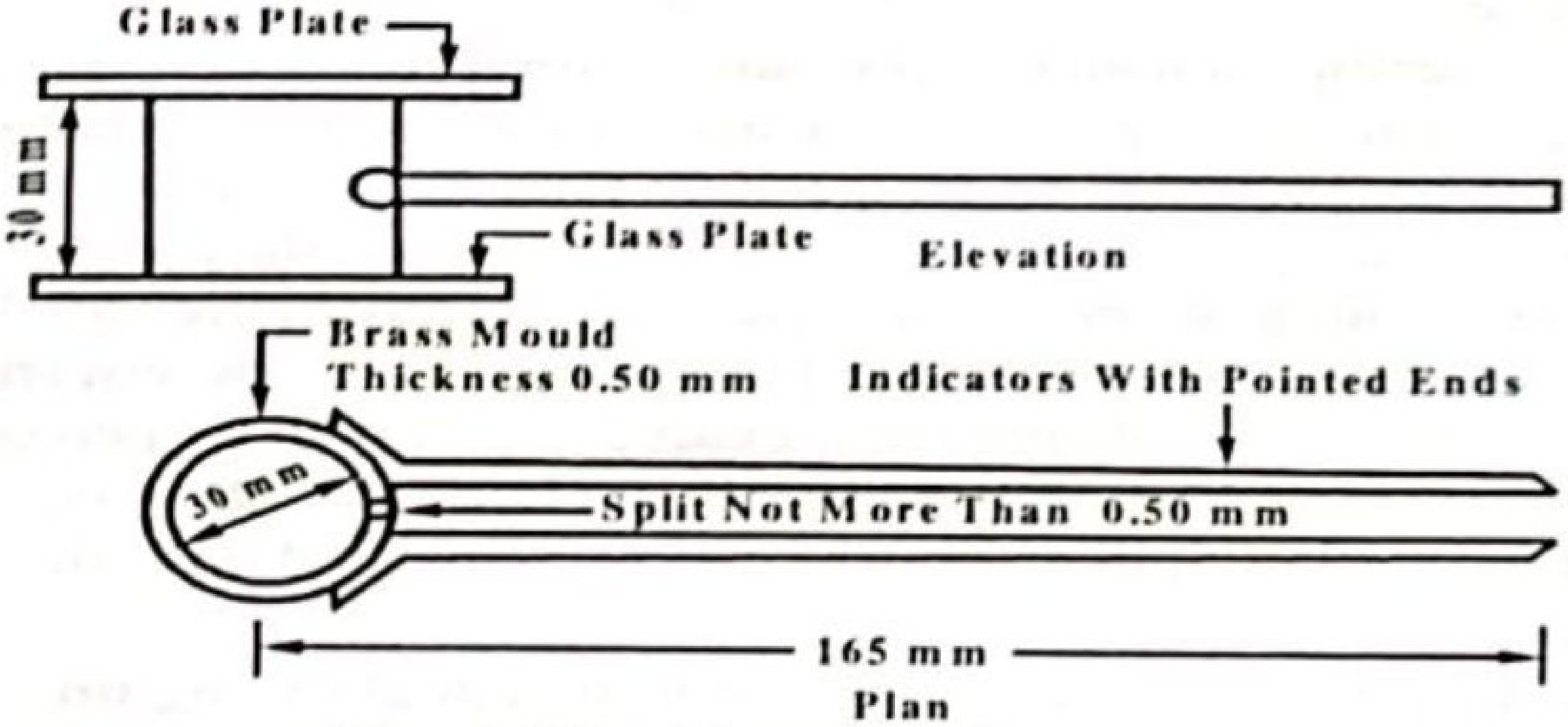


Fig. 1.4 Le Chatelier Apparatus

Now place the mould on the glass sheet and fill it with cement paste ormed by gauging cement with 0.78 time the water required to give a paste of tandard consistency. Now mould is coverd on the top with another glass heet and immersed in water at a temperature of 27° - 32° C and kept there for 24 hours measure the distance between the indicator points. Now whole ssembly is immersed in water again.

Heat the water and brings to boiling point in about 25-30 minutes and eep it boiling for 3 hours. Remove the mould from the water, allow it to cool nd measure the distance between the indicator points. The difference between hese two measurements represents the expansion of cement. This must not xceed 10 mm for ordinary portland cement.

Field Tests for Cement – To check upon the quality of cement, th following field tests are carried out –

(i) The colour of the cement should be greenish grey.

(ii) There should be smooth feeling, when rubbed in between finger

(iii) Whenever hand is put into the cement bag it should feel cool.

(iv) Whenever an amount of cement is thrown into a bucket of wate it should float.

(v) There should not be any lumps in the cement.

Q.30. List out various field tests and laboratory tests of cement. Explai any two tests in details. ***(R.G.P.V., Dec. 201***

Ans. Refer Q.29.

Q.31. What is the importance of initial and final setting time of cement How these times can be suitably controlled ? ***(R.G.P.V., June 201***

Ans. Cement when mixed with water results into paste form, whic gradually becomes less plastic and finally a hard mass is obtained. In th complete process, a stage is reached when a cement paste is sufficiently rigi to withstand a definite amount of pressure. Setting refers to a change from fluid to a rigid state. Setting is mainly caused by a selective hydration of C_3 and C_2S and is accompanied by temperature rises in the cement paste. Initi set corresponds to a rapid rise and final set corresponds to the peak temperatur Initial and final setting of cement are affected by temperature. BS 4550 : Pa 3 : section 3.6 : 1978 specifies that the mixing has to be undertaken at temperature of 20 ± 2°C and minimum relative humidity of 65 percent, and th cement paste stored at 20 ± 1°C and maximum humidity of 90 percent. So a initial and final setting time of cement can be controlled with the control c temperature.

It is essential for proper concreting that the initial setting time should b sufficiently long for finishing operations, i.e. transporting and placing of th concrete.

The paste should not solidify suddenly; it requires considerable time t become fully rigid. The time taken to solidify completely marks the final se which should not be too long in order to avoid delays in the construction proces

In practice, the length of time for which a concrete mixture will remai plastic is usually more dependent on the amount of mixing water used an atmospheric temperature than on the setting time of cement.

Q.32. Name various types of portland cement and explain the laborator procedure for determining initial setting time of cement.

(R.G.P.V., June 2011

Ans. Refer Q.26 and Q.29.

Q.33. What are the uses of cement ?

Ans. There are various uses of cement –

(i) It is used in cement mortar for masonry work, plaster etc.

(ii) It is used in concrete for laying floors, roofs, lintels, beams etc.

(iii) It is used for precast pipes, jallies, piles, fencing posts etc.

(iv) It is used in the preparation of foundations, underground structures etc.

(v) In all cement is used in construction projects whether it is building, bridge, dam, road etc.

Q.34. What do you understand by term lime ?

Ans. Lime is used as a binding material which is used in construction ndustry. It is very useful for preparing mortar. Lime is being used from early days of construction industry. Various famous temples, monuments and various historical buildings were built with the lime-surki mortar.

Q.35. Write down the characteristics of lime.

Ans. A good lime should have following characteristics –

(i) It should slaked easily in water.

(ii) It should be free from fuel ashes and unburnt particles.

(iii) It should not contain impurities, more than 5 percent.

(iv) It should have good setting power under water.

(v) It should be insoluble in acids.

(vi) It should hardens rapidly.

Q.36. Write the some important uses of lime.

Ans. Lime is very much important in construction industry, but it is also very much useful in many other industries. Some important uses of lime are listed below –

(i) For making mortar for brick and stone masonry.

(ii) In production of artificial stones, sand lime bricks.

(iii) In the manufacturing of cement, paint, glass.

(iv) For plastering and white washing.

(v) For making lean lime concrete in foundations and flooring works.

(vi) Used as a refractory material, in lining of furnaces.

(vii) Used as lime terracing for water proofing roofs.

(viii) Used in sugar industry, petroleum refining, water and sewage reatment plants.

TIMBER – TYPES, PROPERTIES, TEST AND USES

Q.37. What do you mean by timber ?

Ans. Timber is an old age building material, the term 'timber' means the wood of sufficient size, which is suitable for engineering construction purpose. It is applied to the tree measuring not less than 60 cm width. Timber is used in building construction in various locations such as beams, trusses, rafter, floors, roofs, doors, windows, poles, staircases, piles, columns etc. The word timber means "to construct or to build". However, the use of timber is going to decrease due to scarcity, high cost of labour and timber, availability of cheaper and stronger material.

Q.38. Discuss different varieties of timber used in engineering applications.

Ans. The different varieties of timber used in engineering applications are as follows –

(i) Hard Wood – The hard wood is derived from broad leafed exogenous trees. It is very hard and difficult to work upon because of it is closed grained and strong. It is non resinous and contains large percentage of acid. Examples – Shisham, Sal, Teak, Oak, Babul, Mahogany etc.

(ii) Soft Wood – It is derived from evergreen conifer trees. It is light in colour. It is resinous and have strong fibers. It is weaker and can split easily. Its texture is soft and regular. Examples – Spruce, Deodar, Chir, Kail, Walnt etc.

(iii) Industrial Timber – The timber which is produced or manufactured in factory by using timber or wood as raw materials is called industrial timber. Industrial timbers are having good strength and they are durable. They can be made termite proof and weathering resistant by giving suitable treatment. They can be made in any desirable shape and size. Following are the varieties of industrial timber –

(a) Plywood (b) Veneers (c) Fibre board (d) Impreg timber.

(a) Plywood – Ply implies thin layer. Plywood is manufactured by cementing together thin board or sheets of wood into pannels or sheet. There are always odd number of layers (plies i.e., 3, 5, 7, 9 etc.). Three or more number of plies are placed one above the other keeping direction of grains mutually right angle to each other (fig. 1.5).These layers are glued well either by application of pressure in hot condition or in cold condition. If pressed hot hydraulic press is employed to work at temperature 150°C-260°C. In cold pressing high pressure of the order of 7 to 14 kg/cm^2 is applied. The main advantage of plywood over the single board is the uniform strength along the length and width. Plywood offers greater resistance to splitting checking with change in moisture contents. Usually synthetic resins are used as adhesive. The plywoods are used for ceiling, doors, furnitures, partition walls, partition, railway coaches, bus body making, formwork etc. Plywood are generally used for indoor works. Following are the thickness and size of it in which plywood is available.

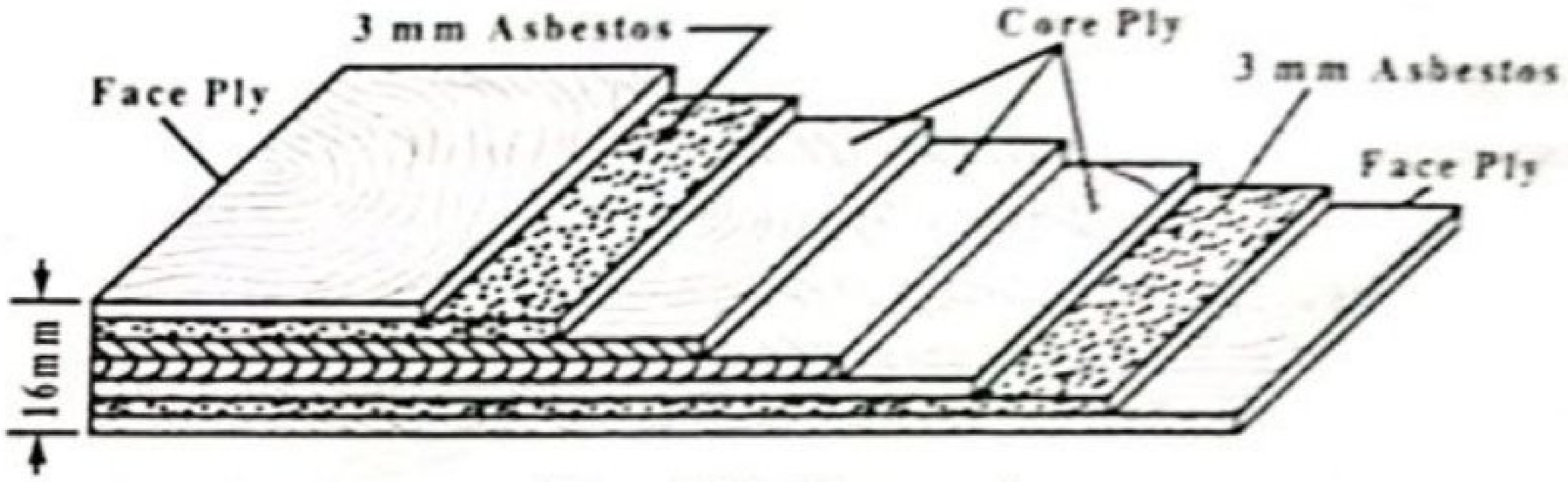


Fig. 1.5 Plywood

3 Ply - 3 mm-6 mm
5 Ply - 5 mm-9 mm
7 Ply - 9 mm-16 mm
9 Ply - 13 mm-16 mm
11 Ply - 19 mm-25 mm

Usual sizes are 240 × 120, 240 × 90, 210 × 120, 210 × 90, 180 × 120, 80 × 90, (cm × cm).

(b) Veneers – Veneers (thin sheets of wood) are produced by rotary cutters where a knife blade is firmly held against a log of good quality of timber which is rotated (like pencil cutter). The sheets as turned out are cut

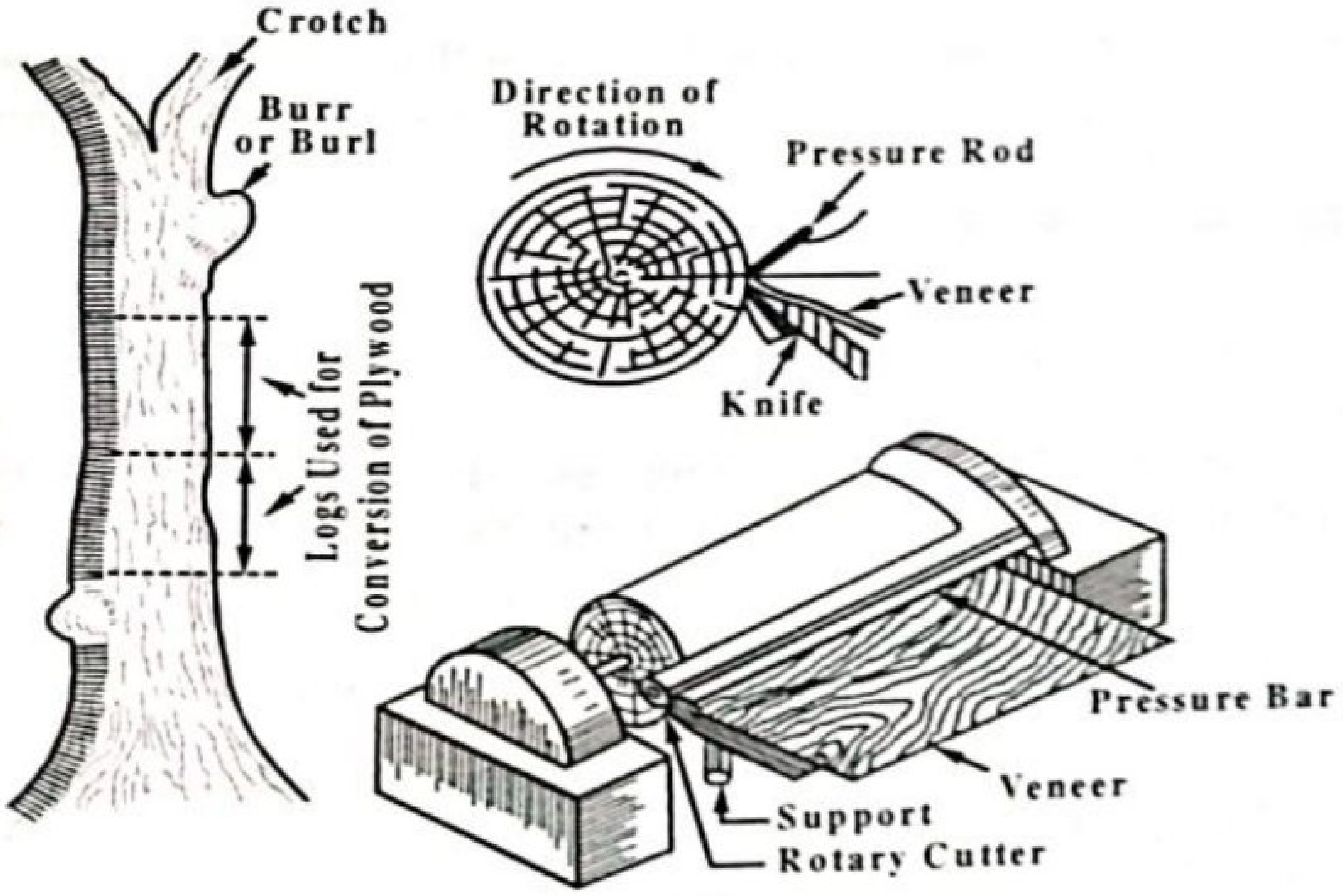


Fig. 1.6 Veneers

into sizes, dired and graded as suitable for cores or faces. Teak, Sissoo and Toon are some of the Indian timbers capable of producing high grade figured veneers of approved merit.

The thickness of veneers varies from 0.40 mm to 6 mm. This process of getting veneer is called as veneering. Veneers are glued with suitable adhesive on the surface of inferior quality of woods. This improves its appearance.

(c) Fibre Board – These boards are also known as pressed board. These are produced by reconstruction of wood hence also called as reconstructed wood [fig. 1.7].These are produced by adopting following step by step procedure.

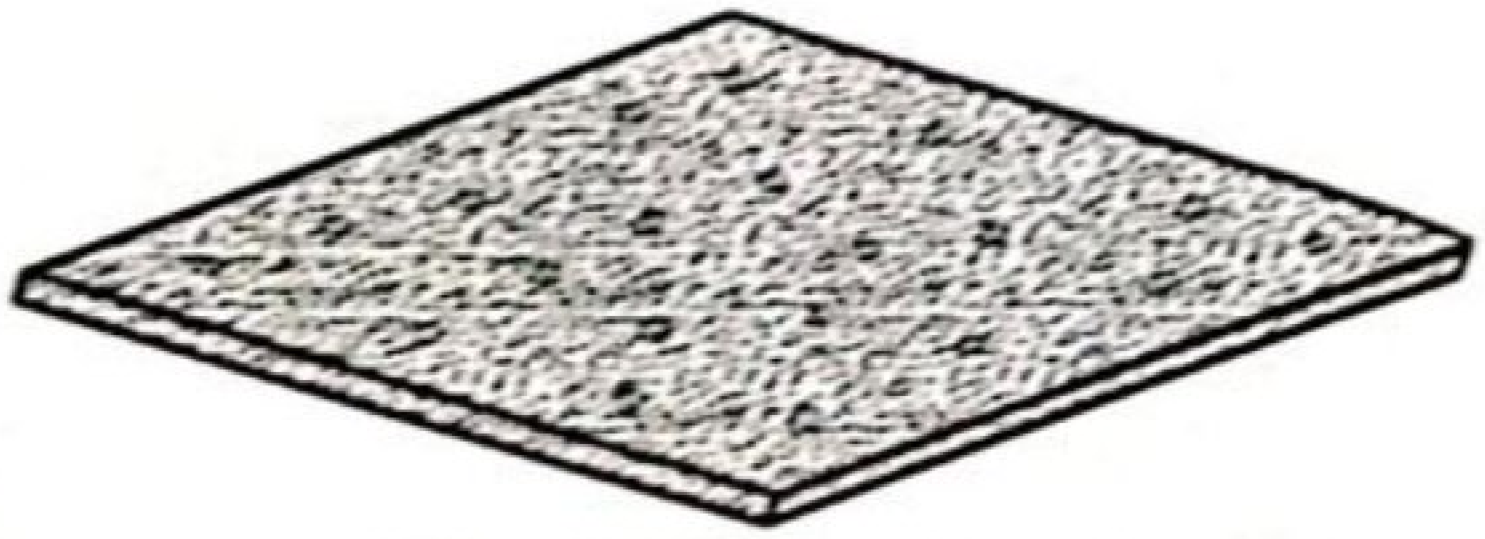


Fig. 1.7 Fibre Board

(1) The wood, bamboo, cane or chipps of the timber are collected and they are boiled in hot water.

(2) Due to boiling, wood fibers get separated out and then put inside an air tight vessel.

(3) The steam is allowed to enter in the vessel and then pressure is suddenly increased to 70 kg/cm^2. This high pressure is maintained for 1/2 a minute.

(4) The steam is now suddenly taken out by releasing the valve. This causes the wooden pieces to explode and in the process the natural adhesive i.e., glue is separated.

(5) The fibers of wood are then flow out and takes some time.

(6) These fibers are cleaned off from the extra gum, if any.

(7) The clean fibers so obtained are spread on fine wire screen in the form of sheet.

(8) Artificial glue is applied and then is it is pressed by steel plates to a higher pressure of 7 kg/cm^2 and then dried. This produces the fibre board. These boards are very commonly used for false ceiling internal finish, construction of partition, flooring. Depending upon their composition and properties, the fiber board are classified as hard wood, particle board, laminated board etc.

(iv) Impreg Timber – This is a type of veneer which is fully or partly covered with thin slime of resin. Usually the resin used for such purpose is phenol formaldehyde.

To prepare impreg timber the veneer of wood are immersed in resin. The resin occupies the space between cells of the wood and waterproof consolidated mass develops. This is cured at a temperature of 150°C-160°C for two hours. The surface so formed is glossy and gives decorative finishing. Impreg timber is commercially available by the tread names such as, Sun mica, Son gloss, Formica, etc. It is very commonly used for moulds, decorative surfaces and in furniture. These timber are not only waterproof, they resist the acidic condition as well. It exhibits less contraction and expansion.

If during the manufacturing process curing is carried out under pressure then timber so formed is called as compreg timber. Strength and durability of compreg timber is more than impreg timber.

Q.39. Describe various defects in timber with the help of neat sketches.
(R.G.P.V., Dec. 2014)

Ans. Defects in timber are generally caused by changes in climatic condition. Some of the important defects and diseases are explained below –

(i) Star Shakes – These are radial splits which are starting from the bark, running in the planes of medullary rays, towards the centre of the tree as shown in fig. 1.8. These are caused due to rupture of tissues as a result of climatic disturbance such as severe frost or fierce heat of the sun during the growth of the tree.

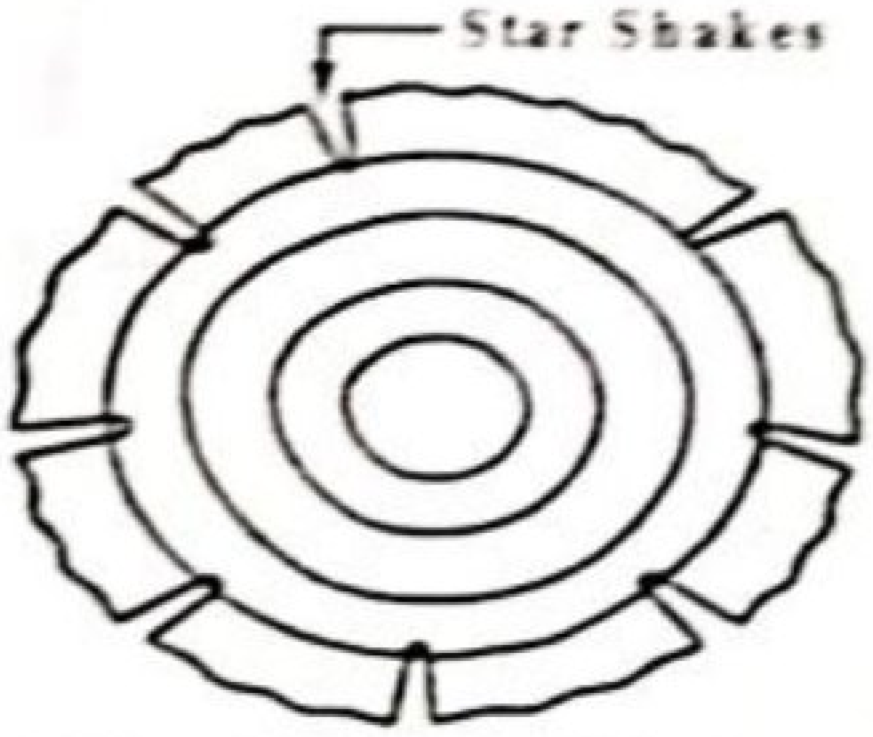


Fig. 1.8 Star Shakes

(ii) Cup Shakes or Ring Shakes – These are curved splits between annual rings, which separate whole or part of one annual ring from the other, as shown in fig. 1.9. These are caused due to excessive bending of a growing tree during a cyclonic weather.

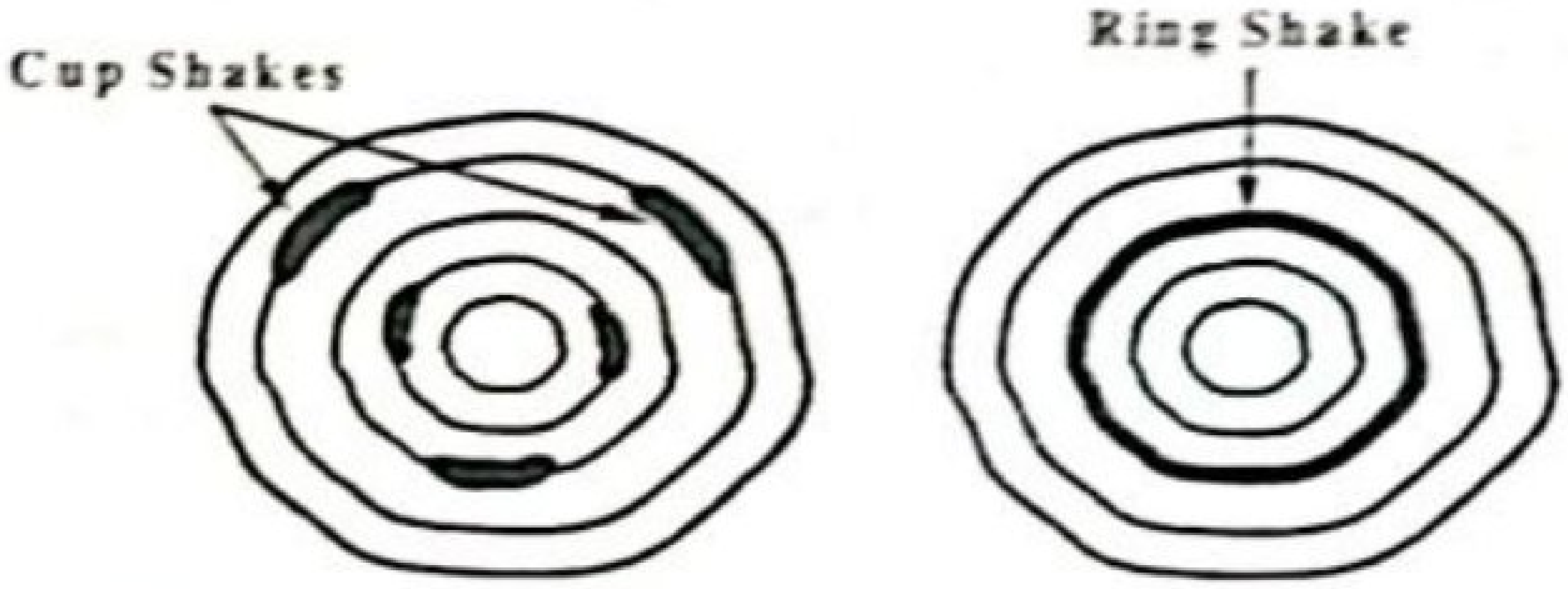


Fig. 1.9 Cup Shakes or Ring Shakes

(iii) Heart Shakes – These are radial splits running from pith towards sap wood in the direction of the medullary rays as shown in fig. 1.10. This defect is develops in matured trees due to shrinkage of heart wood or if tree is cut and kept unbarked for a long time.

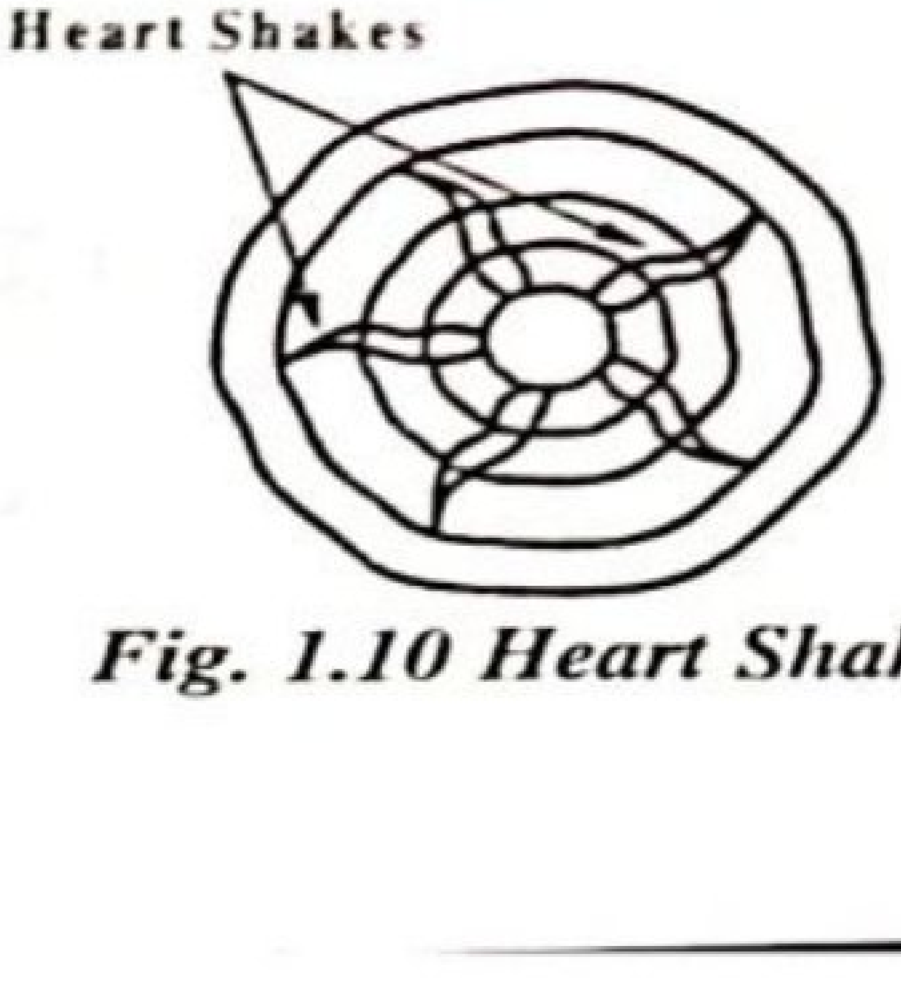


Fig. 1.10 Heart Shakes

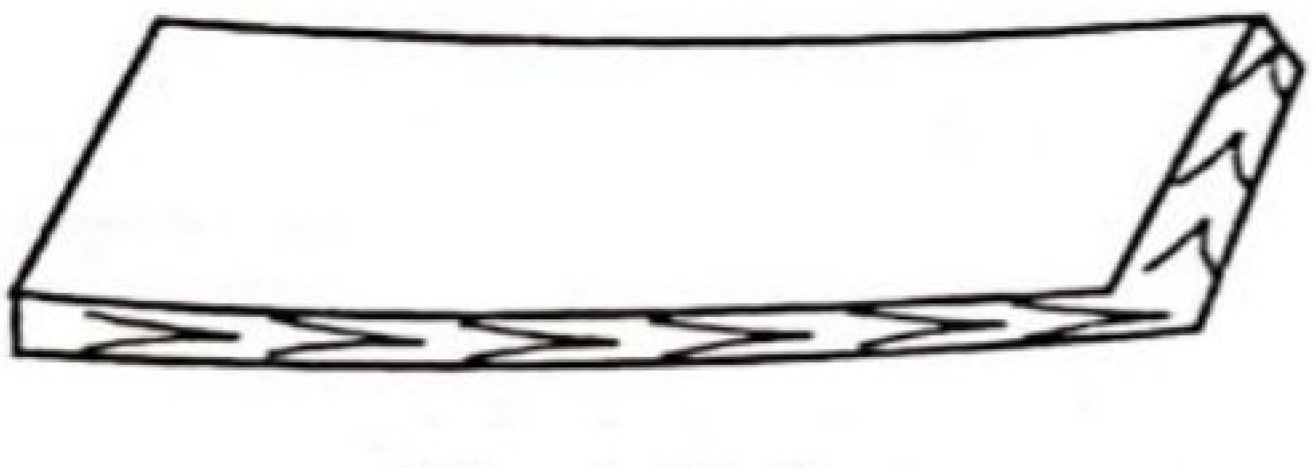


Fig. 1.11 Bow

(iv) Bow – It develops in non-coniferous timber and may develope after felling tree or during conversion and seasoning. Converted timber shrinks, bends in the direction of length as shown in fig. 1.11.

(v) Rind Galls – These are rarely found in a tree. These are typical curved swellings formed upon the trunk of a tree by successive layers of sap wood. The timber in this part is very weak and not durable. See fig. 1.12.

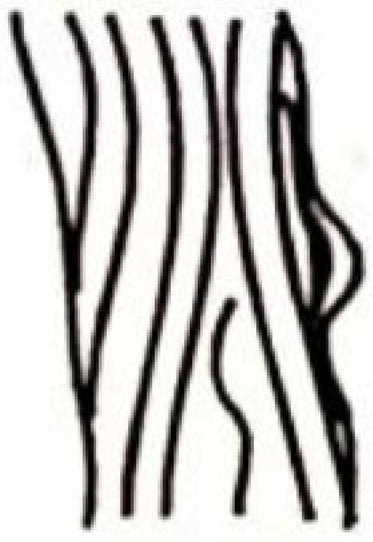


Fig. 1.12 Rind Galls

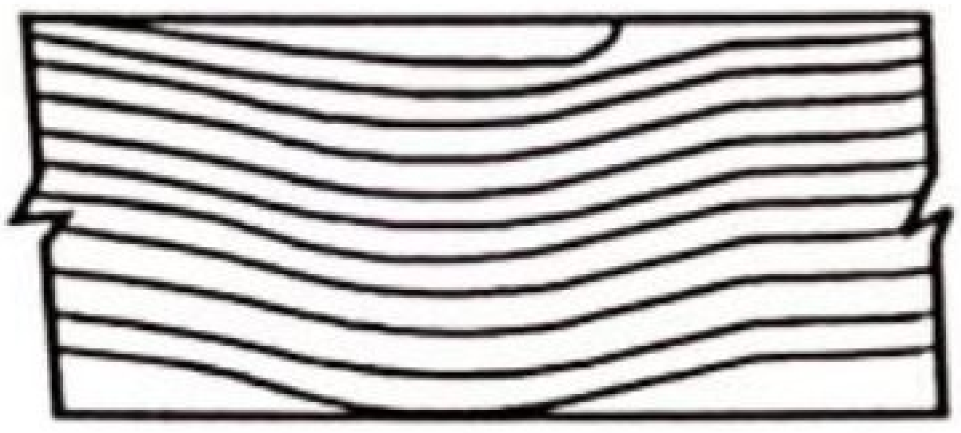


Fig. 1.13 Upset

(vi) Upsets – These are nothing but crippling or buckling of fibres. These are caused by the crushing of fibres when the trunk is felled over a rocky surface. See fig. 1.13.

(vii) Knots – These are dark and hard pieces which are the part of branch incorporated in the body of a tree. These are the sources of weakness in a timber. When knot is intact with surrounding wood, free from any defect, it is called live knot. When it is not held firmly it is called as dead knot. Timbers containing large dead knots are rejected as they are poorer in strength.

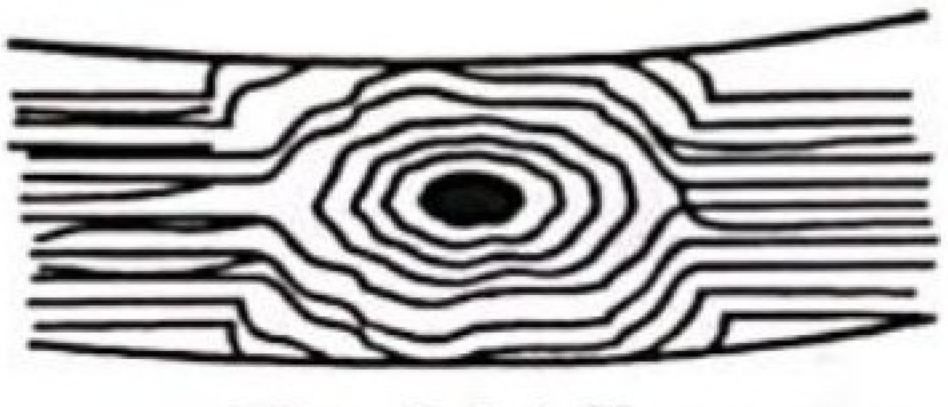


Fig. 1.14 Knot

Q.40. What are the qualities of timber ?

Ans. Following are the qualities of good timber –

(i) Appearance – A good timber should have hard and shining appearance.

(ii) Colour – The colour of timber should always dark. The timber having light colour indicates low strength timber.

(iii) Defects – A good timber should be free from defects such as flaws, shakes, knots, etc.

(iv) Durability – A good timber should be durable enough to capable of resisting the actions of fungi, insects, chemicals, physical agencies and mechanical agencies.

(v) Toughness – A good timber should capable of offering resistance to the shocks due to vibrations.

(vi) Strength – A good timber should have sufficient strength to work as joist, beam, rafter etc. It should possess enough strength in direct and transverse direction.

(vii) Soundness – A good timber should give out a clear ringing sound when struck.

(viii) Hardness – A good timber should hard enough and durable.

Q.41. What do you understand by term seasoning of timber ? What are the different methods of seasoning ? ***(R.G.P.V., Feb. 2005, June 2005)***

Or

What is the importance of seasoning of timber? Describe any one method of seasoning of timber. ***(R.G.P.V., Dec. 2005, June 2011)***

Or

List out various methods of seasoning of timber. (R.G.P.V., Dec. 2015)

Or

Explain the seasoning of timber. ***(R.G.P.V., Dec. 2016)***

Ans. Removal of moisture from timber so as to be in equilibrium with moisture in surrounding atmospheric conditions, where timber is likely to be used is called as seasoning of timber. In other words seasoning of timber means getting rid off all the sap and moisture from it. After seasoning has been done, timber is not liable to be decayed, owing to fermentation of the sap or warp or bend due to uneven expansion or contraction of timber, due to rise and fall of temperature. After seasoning, the timber becomes dry, hard, light in weight, less in bulk and resilient. A well seasoned timber can easily be worked with saw, crack, twist and split. The strength of well seasoned timber is increased.

There are different methods of seasoning like (i) natural seasoning (ii) artificial seasoning.

(i) Natural Seasoning – There are two methods of natural seasoning –

(a) Air Seasoning – It is the best method of seasoning. In this method, water or the moisture is driven out from the timber by a very slow process of evaporation. The object of seasoning is to ensure regular and uniform drying throughout the timber. In this process, the timber balks are stacked under a shed. The timber balks should be kept perfectly horizontal, to avoid twisting of timber during seasoning. The stack should be made on damp proof materials, preferably on cast iron, stones, concrete block etc. The stacks should be kept up from ground at least by 30 cm as shown in fig. 1.15.

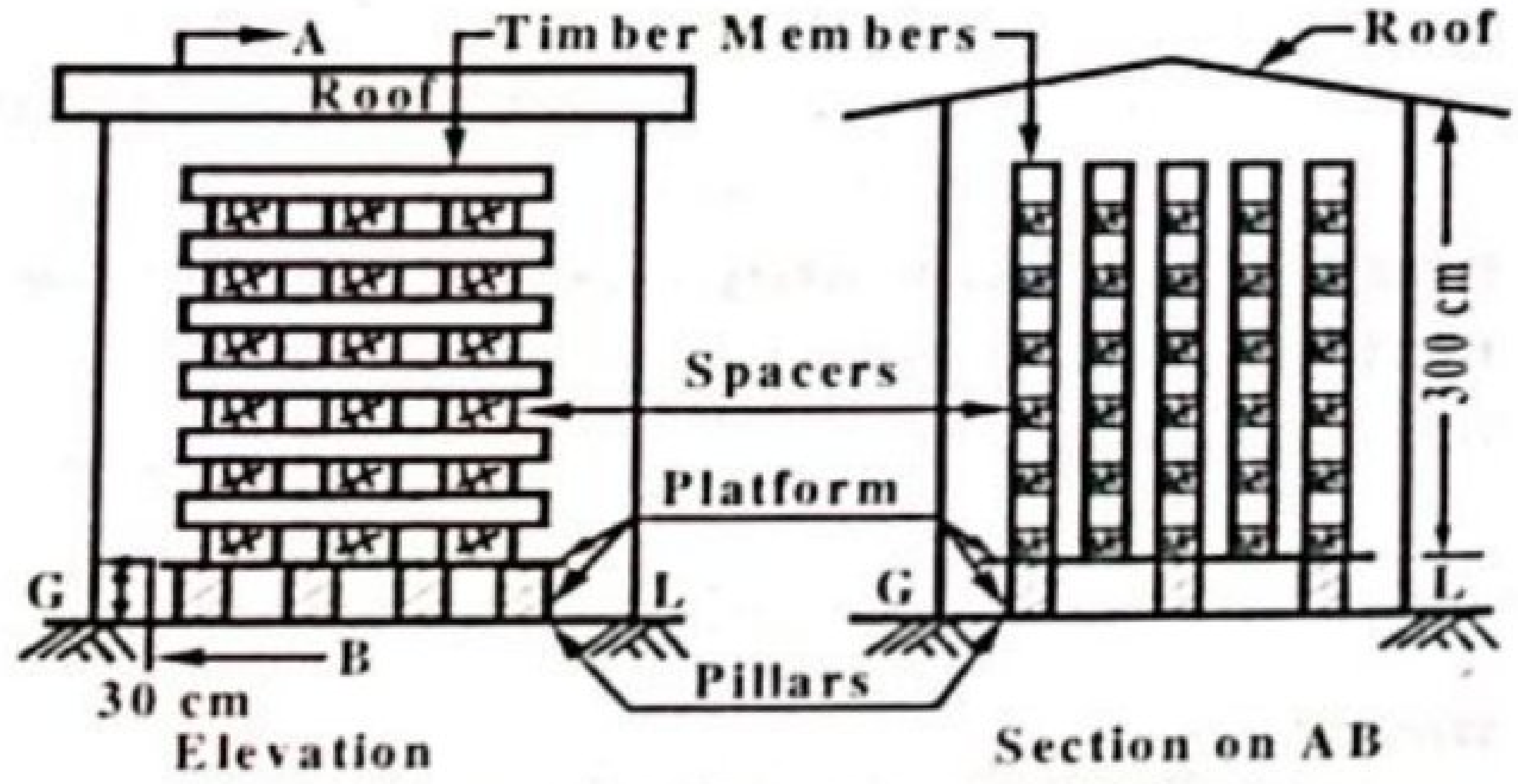


Fig. 1.15 Air Seasoning

(b) Water Seasoning – In this method, the logs are kept immersed in ponds or in running streams with the root ends upstream for three to four weeks. Maximum sap is washed out by this process. The logs should be kept entirely down under water by chaining them. Now after that these logs are kept under shed for free air circulation.

(ii) Artificial Seasoning – There are different methods of artificial seasoning –

(a) Mc Neills Seasoning – This is believed to be the best process of artificial seasoning, as it has no adverse effect on the appearance and strength of timber. Timber seasoned by this method is rendered harder, denser and proof against dry rot. But, it is a costly method of seasoning timber. The time required varies with the nature of the timber, usually from 15 days to two months. In this process, the timbers are stacked in a chamber with one-third air space and containing a large water surface to produce vapour by various hot gases as the products of combustion of fuel in the fireplace within the chamber. Thus, the timbers are subjected to moist warm atmosphere. The chamber is usually built with bricks. The greener the timber when first put into the chamber, better is the result of seasoning.

(b) Hot Air Seasoning – In this process, the timbers are stacked in racks in a hot chamber heated with steam pipes on the floor. Within the hot chamber the timbers are subjected to a swifty moving current of air passing over the hot pipes. The timbers are kept there for about three days at a constant temperature of 90°C. The hot air absorbs sap or moisture content of the timbers.

The moisture-laden air is expelled from the upper part of the chamber and fresh dry air is introduced from the bottom. The process is also known as kiln-seasoning. It renders timber brittle and bleaches deep coloured timber.

(c) Seasoning by Boiling in Water – Water-seasoning can be hastended by using boiling water. The timber is kept immersed in boiling water for four hours. By this process the strength and elasticity of the timber is reduced, although there is less shrinkage. Following the boiling, the timber should be dried slowly under a shed. This method of seasoning is expensive.

(d) Seasoning by Steaming – This is similar to seasoning by boiling, but the timber dries soon after the steaming. Steaming prevents dry rot in timber, but it is expensive.

Q.42. What are the uses of timber ?

Ans. Timber has various uses as follows –

(i) It is used as piles, posts, beams, lintels, doors, windows, roof members etc.

(ii) It is used in rafters, purlins, trusses etc.

(iii) It is used for flooring, roofing, ceilling, panelling etc.

(iv) It is used for interior decoration.

(v) It is used for making furniture, sports goods, railway sleepers etc.

LABORATORY TESTS CONCRETE AND MORTAR MATERIALS – WORKABILITY, STRENGTH PROPERTIES OF CONCRETE, NOMINAL PROPORTION OF CONCRETE, PREPARATION OF CONCRETE, COMPACTION, CURING

Q.43. What do you understand by term mortar ? State different properties and uses of mortar. ***(R.G.P.V., June 2005, 2009)***

Ans. Mortar is a paste made by cement, sand and water or by lime, surki and water. Lime and cement are the binding materials in the mortar. Sand and surki gives the strength to the mortar. They also prevent excessive cracking due to shrinkage of the paste. The strength of mortar decreases as the proportion of sand increases. Mix of 1 cement and 3 sand is the better mix. The water required for better result is 20 to 25 percent as it gives the greatest strength of mortar.

Following properties are required for a good mortar –

(i) It should be easily workable.

(ii) It should develope adequate strength in tension and compression.

(iii) It should set quickly.

(iv) It should bind the bricks or building stones properly.

(v) It should be cheap.

(vi) It should be durable.

(vii) It should maintain the appearance for quite a long period.

(viii) It should be capable of resisting penetration of rain water.

(ix) It should not affect the durability of materials with which it comes into contact.

(x) It should have good consistency.

(xi) It should possess the ability of retaining adequate humidity during transportation and laying over the porous bed.

Different mortars are used for different purposes in civil engineering constructions owing to their plasticity, workability, binding and setting properties.

(i) Mortar is used to form soft layers for bricks and stones in masonry work.

(ii) It is also used to distribute uniformly load over the lower bricks or stone.

(iii) It is also used to bind the bricks and stones with each other.

(iv) It also provide water tightness against weather.

(v) It is used as the plaster or impermeable covering for walls and roofs.

(vi) It is also used as paint, which protect the joints of bricks or stones.

(vii) It is used to fill up the voids, which remains in a structure.

(viii) It is used to repair cracks of any structure.

(ix) It is also used for various ornamental works to improve the general appearance of a building or structure.

***Q.44. Explain various types of mortars used in building construction.* (R.G.P.V., Dec. 2003)**

Ans. There are various types of mortars used in building construction classified according to material used in the mortars.

(i) Cement mortar
(ii) Lime mortar
(iii) Mud mortars
(iv) Hydraulic surki mortar.

(i) Cement Mortar – It consists of cement, sand and water. It is the strongest type of mortar, so as used in the construction of structures subjected to heavy loading. The ratio of cement and sand is normally 1:3 to 1:6 by weight.

(ii) Lime Mortar – They are classified as follows –

(a) Non Hydraulic Lime Mortars – These mortars are prepared by using fat lime with sand. They have light colour. The ratio of lime and sand are normally 1:2 or 1:3 by volume.

(b) Hydraulic Lime Mortar – These mortars are made from class A and class B limes. These mortars has more strength.

(iii) Mud Mortar – It is made up by sticky clay and water, which is pugged until it attains required consistency. It is also called as gara. Sometimes certain fibrous materials like gobber is mixed with it. It is very cheap and locally available. These are used for brick work of ordinary buildings.

(iv) Hydraulic Surki Mortar – Hydraulic surki mortar is made by mixing fat lime and surki. Surki is the fine powder of burnt bricks. It sets very hard under water.

***Q.45. Give general proportion of mortar used for atleast two building components.* (R.G.P.V., Dec. 2006)**

Ans. There are various proportions of cement mortar for various uses as given below –

S.No	Nature of Work	Mortar Type and Composition
(i)	Thick joints in stone masonry.	Hydraulic lime sand mortar (1:2 to 3)
(ii)	Stone masonry in foundations and superstructure of ordinary buildings.	1:2 fat lime surki mortar or 1 part lime, 1 part surki and 1 part sand.
(iii)	Brickwork in arches, plastering inside of walls.	1:5 to 1:6 cement and mortar, or lime surki mortar (1:2) or lime, surkhi and sand (1: 1: 1) mortar.
(iv)	Reinforced brickwork.	1:3 cement sand mortar.
(v)	Mass concrete in foundations, paving tiles, cavity walls, plastering of ceiling and external plastering work etc., where good finish is required.	1:4 cement sand mortar or 1:2 to 3 hydraulic lime mortar.
(vi)	Massive work below ground level especially in water logged areas.	1:3 cement sand mortar or 1:3 lime (eminently hydraulic) sand mortar.
(vii)	Massive works, dams, reataining walls, damp proofing, flooring, etc. where very high finish is required.	1:3 cement sand mortar
(viii)	Pointing work.	1:1 to 1:2 cement sand mortar
(ix)	General R.C.C. works such as slabs, beams and columns, cement concrete flooring etc.	1:2 cement sand mortar.
(x)	Damp proof courses and cement concrete roads.	1:2 cement sand mortar
(xi)	R.C.C. tanks and other retaining	$1:1\frac{1}{2}$ cement sand mortar
(xii)	Highly stressed members of structure	1:1 cement sand mortar
(xiii)	Laying fire-bricks	Fire-resisting, mortar consisting of 1 part of aluminous cement to 2 parts of finely crushed powder of fire-bricks.

Q.46. What do you understand by bulking of sand ? How does it effect the proportioning of concrete ? ***(R.G.P.V., Dec. 2001, June 2005)***

Ans. The presence of moisture in sand increases the volume of sand. This is due to the fact that moisture causes film of water around sand particles which results in the increase of volume of sand. For a moisture content of about 5 to 8 per cent, this increase of volume may be as much as 20 to 40 per cent, depending upon the grading of sand. The finer the material, the more will be the increase in volume for a given moisture content. This phenomena is known as the bulking of sand and it can be expressed in a graphical way as shown in fig. 1.16.

When moisture content is increased by adding more water, the sand particles pack near each other and the amount of bulking of sand is decreased. Thus the dry sand and the sand completely flooded with water have practically the same volume.

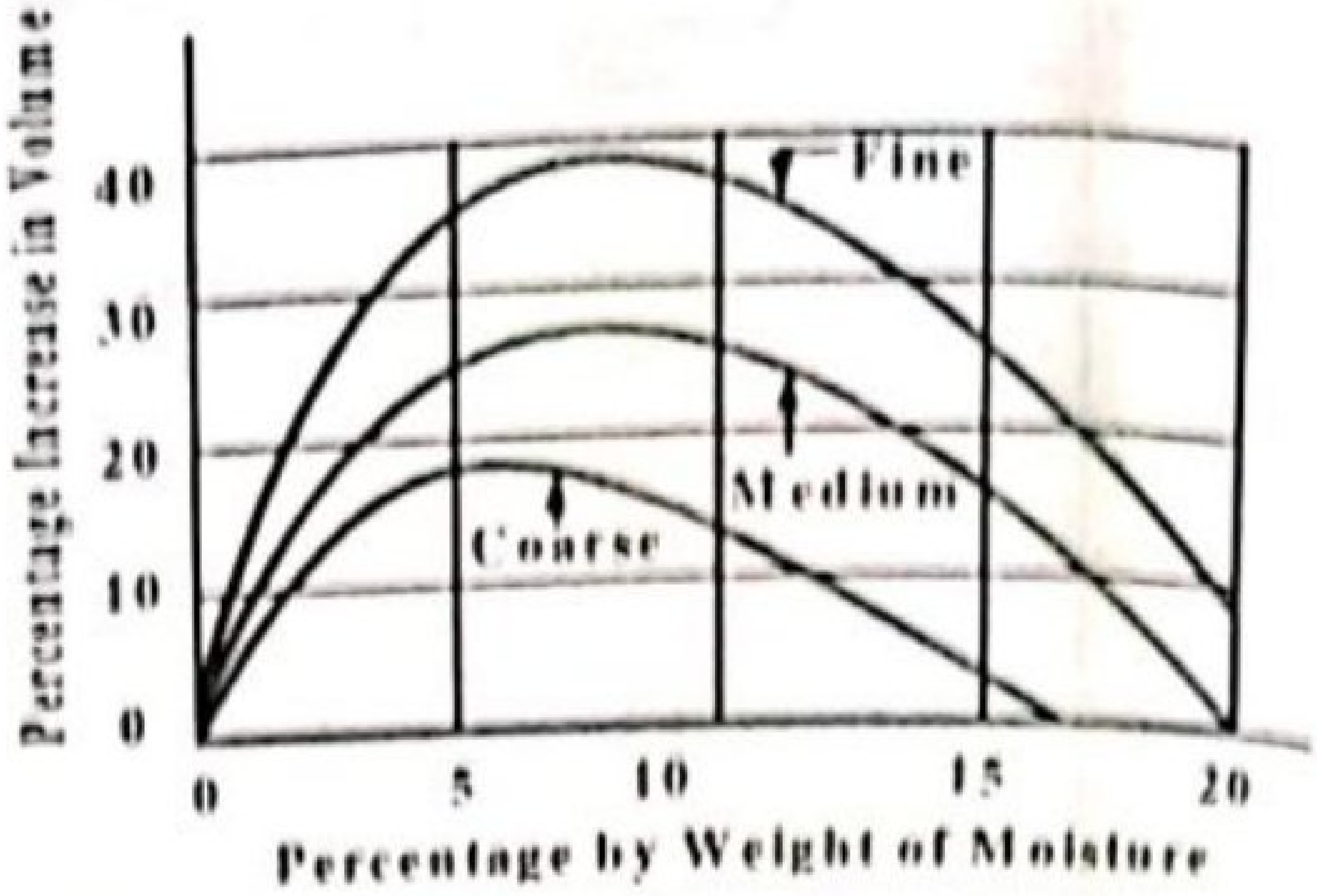


Fig. 1.16 Chart Showing Bulking of Sand

The bulking of sand affects the volumetric proportioning of sand to a large extent. It is more with fine sand and less with coarse sand. If proper allowance is not made for the bulking of sand, the cost of concrete and mortar increases and it results into under-sanded mixes which are harsh and difficult for working and placing.

Q.47. Define cement concrete and mention its properties.
(R.G.P.V., June 2015)

Ans. Cement concrete is the mixture of cement, sand, aggregates and water. Cement concrete is the major building material in the construction industry. It can be easily moulded into durable structural members. The volume of aggregates in concrete varies from 78 to 66 percent.

In concrete, sand is used as an fine aggregate, gravels and crushed stones are used as coarse aggregates. The cement acts as a binding material which forms a paste with water and on hardening this cement paste holds coarse and fine aggregates together to form a solid mass.

The cement concrete possesses the following properties –

(i) The thermal expansion of concrete is approximately 0.4 mm per metre.

(ii) Concrete shrinks as it dries and expands again on wetting and the extent of movement depends upon the modulus of elasticity of the cement.

(iii) It binds rapidly with steel and as it is weak in tension, the steel reinforcement is placed in cement concrete at suitable places.

(iv) It has tendency to be porous.

(v) It has high degree of abrasion resistance.

(vi) It has high degree of electrical resistance.

(vii) It is more economical than steel.

(viii)It has a high compressive strength.

(ix) It is free from corrosion so as it has no effects of atmospheric agents on it.

(x) It hardens with time and this process of hardening is continue to long time and after long time it attains the sufficient strength.

Q.48. What are the different uses of concrete ?

Ans. There are different uses of concrete –

(i) Concrete is extensively used in construction of various structures such as buildings, bridges, dams, canals, barrages, reservoirs, pavements, railway sleepers, tanks, retaining walls, tall structures, under water structures, chimneys, tower, docks and harbours etc.

(ii) Concrete is used for construction of various architectural compositions such as vaults, domes, shells, bridges etc.

(iii) Concrete is also used in prestressed construction.

Q.49. What do you understand by workability of concrete ?
(R.G.P.V., June 2007, Jan./Feb. 2008)

Or

How workability of concrete can be increased ? (R.G.P.V., Dec. 2014)

Or

What do you understand by the term workability ? Explain.
(R.G.P.V., June 2016)

Ans. The term workability indicate the ease or difficulty with which the concrete is handled, transported and placed. The amount of water present in the concrete should be in proper ratio. If water is much more than required, it will result in non-uniform composition of concrete. If water is less than required it will result in difficulty to handle and place it in position. The concrete should enable to be fully compacted with given efforts at site. Generally a higher water-cement ratio is required for good workability. In actual, function of water is to lubricate the concrete. The concrete which is easy for handling and placing is an workable concrete. The lubricant should be in such a manner so it produce concrete without segregation, without loss of homogeneity and to finish it sufficiently easily.

Q.50. Define the term workability. Discuss various factors which affect workability of concrete. (R.G.P.V., June 2013)

Or

What do you mean by workability of the concrete ? Explain about the various factors affecting it. (R.G.P.V., June 2014)

Ans. **Workability** – Refer Q.49.

Factors – Following are the various factors which affect workability of concrete –

(i) Water Content of the Mix – This is the single most important factor governing workability of concrete. A group of particles requires a certain amount of water. Water is absorbed on the particle surface, in the volumes between particles, and provides "lubrication" to help the particles move past one another more easily.

(ii) Influence of Aggregate Mix Proportions – Increasing the proportion of aggregates relative to the cement will decrease the workability of the concrete. Also, any additional fines will require more cement in the mix. An "oversanded" mix will be permeable and less economical. A concrete deficient of fines will be difficult to finish and prone to segregation.

(iii) Aggregate Properties – The ratio of coarse/fine aggregate is not the only factor affecting workability. The gradation and particle size of sands are important. Shape and texture of aggregate will also affect workability. Spherical shaped particles will not have the interaction problems associated with more angular particles. Also, spherical shapes have a low surface/volume ratio, therefore, less cement will be required to coat each particle and more will be available to contribute to the workability of the concrete. Aggregate which is porous will absorb more water leaving less to provide workability.

(iv) Time and Temperature – In general, increasing temperature will cause an increase in the rate of hydration and evaporation. Both of these effects lead to a loss of workability.

(v) Loss of Workability – Workability will decrease with time due to several factors; continued slow hydration and during dormant period, loss of water through evaporation and absorption, increased particle interaction due to the formation of hydration products on the particle surface. Loss of workability is measured as "slump loss" with time.

(vi) Cement Characteristics – Cement characteristics are less important than aggregate properties in determining workability. However, the increased fineness of rapid-hardening cements will result in rapid hydration and increased water requirement, both of which reduce workability.

(vii) Admixtures – In general, air-entraining, water-reducing, and set-retarding admixtures will all improve workability. However, some chemical admixtures will react differently with cements and aggregates and may result in reduced workability.

Q.51. Explain briefly the factors that affect the workability of concrete.
(R.G.P.V., Dec. 2016)

Ans. Refer Q.50.

Q.52. Discuss the common ingredients of concrete.

Ans. Cement, aggregates, water are the ingredients of concrete. Aggregate may be fine aggregates as sand or coarse aggregates as gravel and crushed stone.

(i) Cement – It is used as the binding material and acts as a binder for coarse and fine aggregates. Generally ordinary portland. cement is used to form concrete. Initial setting time of good cement should not be less than 30 minutes and final setting time should not exceed 10 hours.

(ii) Aggregates – The granular materials generally inert chemically such as natural sand, gravels, crushed stones and air cooled iron blast furnace slag, are called aggregates. If only cement is used for the construction, the concrete will result in shrinkage and ultimately cracks are develop. So as to avoid these cracks, aggregates are used. These aggregates are bound together by means of cement. The aggregates are classified into two categories such as fine and coarse aggregates. The material which is passed through sieve no. 480 is called fine aggregates and which retained on sieve no. 480 is called coarse aggregates. These aggregates should be clean, sharp, angular, well graded, hard, durable and free from foreign matters.

(iii) Water – The water to be used in making concrete should confirm to the drinking water standard. It is least expensive but most important ingredient of concrete. The water, which is used for making concrete should be free from acids, alkalies, salts, oil, grease and decayed vegetable matters. The amount of water should be of that, which will produce concrete of required quality.

Q.53. Write down nominal proportion of concrete.

Or

Write short note on proportioning of concrete. (R.G.P.V., Dec. 2010)

Ans. The process of determining the proportion of cement of fine aggregates and coarse aggregates for concrete mix is called ***proportioning of concrete***. The best concrete can be obtained by mixing the ingredients in correct proportion. Proportioning of ingredients can be done by trial so as in this procedure weigh the ingredients of concrete and mix them to the same consistency as it is required in the work. Ingredients for concrete are fine aggregates, coarse aggregates, cement and water. The ingredients are depends upon the nature of the work and availability of material. Gradation of coarse and fine aggregates affects the solidity of cement concrete. A cement concrete having good proportions of aggregates and cement will have solidity between 0.80 to 0.84. For the same coarse and fine aggregates, the strongest concrete is that which contains greatest percent of cement in a unit volume of concrete as well as for the same percent of cement and the same aggregates, the strongest concrete is that which gives greatest solidity. The ideal proportion of the concrete will be that, which produces greatest strength and solidity at the least cost. In estimating the quantities of ingredients for cement concrete it should be kept in mind that voids in coarse aggregates are fill up by sand and voids in fine aggregates are fill up by cement. So as the total increase in the volume of the concrete will slightly increase the quantity of coarse aggregates.

Proportions of ingredients usually adopted in cement concrete for different works are given in table 1.2.

Table 1.2

S.No.	*Proportion*	*Nature of Work*
(i)	1 : 1 : 2	Steel grillage foundation, concrete works under water, foundation for erection of machines.
(ii)	$1:1\frac{1}{2}:3$	Concrete works for docks, water structures, reservoirs.
(iii)	1 : 2 : 4	Reinforced concrete works, erection of high voltage line towers, bridge and tunnel works.
(iv)	1 : 3 : 6	Heavy walls, retaining walls, abutments, piers, arches and floors.
(v)	1 : 4 : 8	Mass concrete, backing for brick or stone masonry, concrete blocks.

From table 1.2, it is noticed that cement concrete is made by mixing the cement, fine aggregate and coarse aggregate in different proportions such as 1 : 1 : 2, $1:1\frac{1}{2}:3$, 1 : 2 : 4, 1 : 3 : 6, 1 : 4 : 8. The proportions of mix 1 : 1 : 2 and $1:1\frac{1}{2}:3$ are mostly used for water structures. The most commonly used mix of cement concrete is 1 : 2 : 4. The mix proportions of 1 : 3 : 6 and 1 : 4 : 8 are used as mat concrete or lean concrete.

Q.54. Explain the term water cement ratio.

(R.G.P.V., Jan./Feb. 2008, June 2009, Feb. 2010)

Ans. Strength of concrete depends upon the strength of cement paste and strength of cement paste depends upon the dilution of paste. The strength of cement paste increase as cement increases and decreases with air and water content. Water react with the cement and cause setting and hardening of concrete. If the water lubricates in the aggregates and it facilitates the passage of cement through voids which impart strength to the concrete.

In actual, water required is about 0.50 to 0.60 times the weight of cement. The ratio of the amount of water to the amount of cement by weight is termed as the water-cement ratio. The strength and quality of concrete depends upon this ratio. The quantity of water is usually expressed in litres per bag of cement. If water required for 1 bag of cement is 30 litres, the water-cement ratio is equal to 30/50 = 0.6. The amount of water should be such that it should impart reasonable degree of workability to concrete. The excess water affects the strength and durability of concrete.

Q.55. What are the factors affecting the choice of mix proportions ?

Ans. There are ***various factors those effects*** the choice of mix proportions –

(i) Strength (ii) Workability

(iii) Types of aggregates (iv) Grading of aggregates.

(i) Strength – The mix should be designed for a considerably mean strength required for structural use.

(ii) Workability – The term workability indicate the ease or difficulty with which the concrete is handled, transported and placed. The amount of water present in the concrete should be in proper ratio. If water is much more than required, it will result in non-uniform composition of concrete. If water is less than required it will result in difficulty to handle and place it in position.

(iii) Types of Aggregates – The shape of aggregates should be irregular (cubica l) and surface of aggregates should have rough texture.

(iv) Grading of Aggregates – The grading of aggregates is the art of doing gradation (Particle size distribution) of an aggragate as determined by sieve analysis.

Fine and coarse aggregates to be used in a concrete mix, should be well graded because grading of an aggregate has considerable effect on workability, uniformity and finishing qualities of plastic concrete.

Q.56. Discuss various methods of proportioning concrete.

Ans. The ***various methods of proportioning*** concrete are –

(i) Arbitrary method (ii) Trial mixtures method

(iii) Minimum voids method.

(i) Arbitrary Method – In this method one part of cement, M parts of fine aggregate and 2M parts of coarse aggregate are taken as the basis.

The quantity of water required for mixing is determined by according to desired workability.

By this method such mixes as 1 : 1½ : 3 (one part cement, 1½ parts fine aggregate, 3 parts coarse aggregate), 1 : 2 : 4, 1 : 3 : 6, 1 : 4 : 8, are arbitrarily chosen by volume.

These days the ratio of fine to coarse aggregate is not taken as 1 : 2 as experiments have shows that the quantity of fine aggregate needed is more than 50% of the coarse aggregate; thus the ratio of coarse to fine aggregate; may be varied from 1½ to 3½.

Limitations – The main drawbacks of this method are –

(a) The lack of proper control over the quantity of water that goes into a batch of concrete tends to result in a concrete of varying strength and denseness.

(b) The fixed specified proportions of cement, fine aggregate and coarse aggregate do not permit taking advantage of favourable types and grading of aggregates to secure a workable mix at the least possible cost of materials, and without harm to the strength of the concrete.

However, this method is simple and if carefully considered gives fairly satisfactory results.

(ii) Trial Mixtures Method – The procedure is as follows –

(a) A certain weight of cement, fine aggregate, coarse aggregate and water are put into a graduated cylindrical vessel and tamped.

(b) The vessel is emptied after noting the height of the upper surface.

(c) The vessel is then cleaned carefully and the method repeated for several trial mixtures in varying proportions.

The mixture that gives the smallest volume for the same weight i.e., one which is the densest is adopted.

This method is quite suitable for impermeable construction.

(iii) Minimum Voids Method – This method is based on the principle that the concrete which has the minimum voids is the densest and strongest. Amount of fine aggregate should be such as to fill the voids.

Q.57. How is the cement concrete prepared ? Describe in detail beginning with proportioning to placement of concrete in the form work.
(R.G.P.V., June 2007)

Or

Mention and describe the various steps involved in production of concrete.
(R.G.P.V., Dec. 2011)

Ans. The ingredients of good concrete and bad concrete are the same, only difference is the care taken during the manufacture of concrete. It is necessary to take great care in each stage of the manufacture of concrete for producing good quality concrete. The various stages of manufacture of concrete are –

(i) Batching
(ii) Mixing
(iii) Transporting and placing
(iv) Compacting
(v) Curing
(vi) Finishing.

(i) Batching – The measurement of materials for making concrete is known as batching. There are two methods of batching –

(a) Volume batching (b) Weight batching.

(a) Volume Batching – In this method, ingredients of concrete are batched by volume. It is not good method. Weight of the volume of dry sand is more than the same volume of the moist sand. The amount of solid granular material in a cubic metre is an indefinite quantity. So as concrete materials are measured by weight. Cement is always measured by weight. It is never measured in volume. The volume of one bag of cement is taken as thirty five litres. Gauge boxes are used for measuring the fine and coarse aggregates. The volume of gauge box is made equal to the volume of one bag of cement.

Water may be measured in kg or litres as convenient. The quantity of water required is a product of one kg per litre.The quantity of water required is a product of water-cement ratio and the weight of cement. If the water-cement ratio is 0.6, then quantity of mixing water required per bag of cement is 0.6 × 50.00 = 30 kg or 30 litres.

(b) Weight Batching – It is the correct method of measuring the materials. For important concrete structures weigh batching system should be adopted. Different types of weigh batchers are available.

(ii) Mixing – The process of rolling, folding and spreading of particles is known as the mixing of concrete. The materials should be mixed thoroughly for the production of uniform concrete. It should also keep in mind that cement paste completely covers the surfaces of aggregates. There are two methods adopted for mixing concrete –

(a) Hand mixing (b) Machine mixing.

(a) Hand Mixing – It is done only for small works. In this method 10 per cent more cement is added, because of the mixing by hand cannot be done thorough and efficient. It should be done over and impervious concrete floor. Firstly fine and coarse aggregates are spread out in alternate layers. Now cement is pour on the top of it and mix them by a shovel. Now water is sprinkled-over the mixture and simultaneously turned over. The operation is continue till a good uniform, homogeneous concrete is obtained.

(b) Machine Mixing – In case of large works, the mixing of concrete is done by machine known as mixer. It is efficient and economical, when the quantity of concrete to be produced is large.

In machine mixing, all the materials of concrete including water, are collected in a revolving drum and the drum is rotated for certain period. The resulting mix is then taken out from the drum.

Machine mixing produces concrete of better quality. The water should be enter the mixer at the same time or before the materials are placed. The concrete mixer should be thoroughly washed and cleaned after use. The concrete discharged by the mixer should be consumed within 30 minutes.

(iii) Transporting and Placing of Concrete – The concrete, as it comes out from the mixer, it is ready for transportation and placed on the formwork. There are various equipments, those are used for transportation of concrete. The precaution to be taken while transporting concrete is that the homogeneity obtained at the time of mixing should be maintained while being transported to the final place of deposition. For ordinary building works, the human ladder is formed and concrete is conveyed in pans from hand to hand. For important and large works various mechanical devices such as dumpers, trucks, mixers, buckets, chutes, belts, pumps, hoist etc. may be used.

Transportation should be in such a manner so that there is no segregation of the aggregates. The concrete should be dropped vertically from a reasonable height. Stiff mix should be used in case of vertical laying of concrete otherwise bleeding will takes place.

Q.58. What is concrete and how is it made ? Also mention factors affecting strength of concrete. ***(R.G.P.V., Dec. 2013)***

Ans. Refer Q.47, Q.57 and Q.53.

Q.59. What is concrete ? Describe the process of preparation of concrete. ***(R.G.P.V., Dec. 2012)***

Ans. Refer Q.47 and Q.57.

Q.60. Explain the term compaction of concrete. ***(R.G.P.V., Jan./Feb. 2008)***

Ans. Compaction of concrete means, expelling the entrapped air from the concrete. In the process of placing of concrete, air is entrapped in the concrete. If this air is not removed fully, the concrete loses strength considerably. Compaction of concrete gives maximum density to the concrete. A presence of 5% of voids reduces the strength upto 30% of concrete. To achieve the full compaction and maximum density, it is necessary to use a mix with adequate workability. The following methods are adopted for compacting the concrete –

(i) Hand compaction
(ii) Compaction by vibration
(iii) Compaction by pressure and jolting
(iv) Compaction by spinning.

(i) Hand Compaction – Hand compaction of concrete is adopted only for unimportant concrete works. In hand compaction, concrete is compacted by ramming, tamping, spading and slicing with suitable tools. Hand compaction is also adopted in situation, where a large quantity of reinforcement is used, which cannot be normally compacted by mechanical means. Wherever feasible hand compaction should preferred because the use of vibrator may lead to the segregation of the aggregates. The hand compaction required fairly wet concrete.

(ii) Compaction by Vibration – Vibrators are the mechanical devices which are used to compact the concrete in the framework. The modern high frequency vibrators are used to place the concrete economically. The action of vibration is to set the particles of fresh concrete in motion and reducing the friction between them. Vibration improves the quality of concrete. The use of vibrators reduced the compaction time. Hence vibrators are used where the rapid progress of work is required. Vibrators are helpful to deposite the concrete in small openings or places. Vibration is essential for production of good concrete. Vibration is necessary, if available aggregates are of poor quality. Generally following types of vibrators are used –

(a) Immersion or internal vibrators
(b) Surface vibrators
(c) Form or shutter vibrators
(d) Vibrating tables.

Q.61. What do you mean by curing of concrete ? What are the various methods of curing ? ***[R.G.P.V., June 2005, Dec. 2006, June 2008(N)]***

Or

Write short note on curing of concrete. ***(R.G.P.V., June 2009, Feb. 2010, Dec. 2010)***

Or

What is the mean of curing ? Also state the principle behind the curing. ***(R.G.P.V., Dec. 2015)***

Or

Define curing. ***(R.G.P.V., June 2016)***

Ans. Curing is the process of keeping the concrete moist and warm enough so that the hydration of cement can continue. In fact concrete derives strength by the hydration of cement. In other words, curing is the process of maintaining a satisfactory moisture content and a favourable temperature in concrete, so that hydration of cement may continue until the concrete developes desired properties. If curing is neglected in the early period of hydration, the quality of concrete will experience a sort of loss. If curing is not done well after placing of concrete, it will not give the desirable bond and strength characteristics.

For the ordinary portland cement, the curing period is about 7 to 14 days. If curing of concrete is not done properly it will reduced the compressive and flexural strengths. The frost and weathering resistances are decreased due to improper curing. The cracks are developed due to plastic shrinkage, drying shrinkage and thermal effects, if curing is not done well.

Most commonly employed methods of curing are as follows –

(i) Water curing (ii) Membrane curing
(iii) Application of heat (iv) Application of curing compounds.

(i) Water Curing – It is the best method of curing. In this method, water is applied on the concrete surface for certain duration.

There are following ways of water curing –

(a) Ponding (b) Spraying (c) Wet covering.

Slabs, roofs, etc. are covered under water by developing water pond on the concrete surfaces. Vertical walls, columns, plastered surfaces are cured by sprinkling of water on it. Vertical surfaces are also cured by using some wet coverings such as gunny bags, cloth, jute matting, straw etc. Horizontal surfaces are kept wet by covering concrete with wet sand, saw dust etc.

(ii) Membrane Curing – In some places where there is acute shortage of water, membrane curing is adopted. Generally water mixed for making concrete is more than sufficient to hydrate the cement. Membranes are applied all around the concrete which will effectively seal off the concrete. The membranes seal over the concrete by means of a firm impervious film to prevent moisture in concrete from escaping by evaporation. This prevention of moisture in concrete will worked as a curing of concrete.

(iii) Application of Heat – When concrete is subjected to higher temperature, it accelerates the hydration process and results in higher development of strength. Concrete cannot be subjected to dry heat because of moisture is also an essential requirement. Therefore for achieving this goal concrete is required to subjected, the steam curing. Steam curing will give not only economical advantages, but also technical advantages to the concrete. It is applied generally on prefabricated concrete elements.

(iv) Application of Curing Compounds – There are certain curing compounds those keeps the concrete wet. Calcium chloride is the one curing compound. It can be used as a surface coating or as admixture. Calcium chloride is a salt, it shows affinity for moisture. The salt, not only absorb the moisture from atmosphere but also retain it at the surface. It keeps the concrete wet for a long time to promote hydration.

Q.62. Differentiate between bleeding and segregation.

(R.G.P.V., June 2013)

Ans. **Bleeding** – It is the particular form of segregation, in which some of the water from the concrete comes out to the surface of the concrete. Bleeding is takes place in highly wet mix, badly proportioned and insufficiently mixed concrete. In case of roof slabs or road slabs and when concrete is placed in rainy weather excessive bleeding is observed. Due to bleeding water comes out from the concrete and accumulates at the surface of the concrete. Certain quantity of cement is also comes out from to the surface. When the surface is worked up with the trowel and floats, the aggregates are goes down and the cement and water comes out to the top surface. This formation of cement paste at the surface is known as "Laittance". This laittance produces dust in summer and mud in rainy season.

Segregation – Segregation is the separation of the constituent materials of concrete. A good concrete contain proper distribution of all the ingredients of concrete. If coarse aggregates shows the tendency of separating out from the concrete, the sample is said to be showing the tendency for segregation. This type of concrete is weak due to lack of homogeneity and its having reduction of desirable properties.

Segregation is of three types, firstly the coarse aggregates seperating out from the concrete, secondly, the paste of cement is separating out from coarse aggregate and thirdly water is separating out from the rest of material.

From the above discussion, it results that the tendency for segregation can be remedied by proper proportioning of mix, by proper handling, transporting, placing, compacting and finishing. Slump test and flow test gives an fair idea of the quality of concrete with respect to segregation.

Q.63. Differentiate between concrete and mortar. (R.G.P.V., June 2013)

Or

Differentiate between cement mortar and cement concrete.
(R.G.P.V., June/July 2006, Jan./Feb. 2007, June 2007, March/April 2010)

Ans. Differences between mortar and concrete are given below –

S.No.	*Mortar*	*Concrete*
(i)	It is the mixture of cement, sand and water.	It is the mixture of cement, sand, aggregates and water.
(ii)	Its having less compressive strength.	Its having more compressive strength than mortar.
(iii)	It is generally used for masonry work and plaster.	It is generally used for construction of roofs, columns, beams etc.

Q.64. What do you mean by M-10, M-15, M-20 and M-30 concrete ?

Or

What do you mean by M-30 concrete ? Explain. (R.G.P.V., June 2014)

Ans. Concrete mixes are classified by its grade having specified crushing strength at 28 days as measured in standard conditions with 150 mm sizes cubes, i.e. the grade of concrete corresponds to its characteristics strength. M-30 shows the crushing strength of that cube having size 150 mm at 28 days is 30 N/mm^2. M-20 shows the crushing strength of that cube having size 150 mm at 28 days is 20 N/mm^2. M-15 shows the crushing strength of that cube having size 150 mm at 28 days is 15 N/mm^2. M-10 shows the crushing strength of that cube having size 150 mm at 28 days is 10 N/mm^2.

Q.65. What are the various tests for concrete ? Explain them in detail.
(R.G.P.V., Dec. 2002)

Or

What tests are performed to assess the quality of cement concrete ? Mention any two in detail. ***(R.G.P.V., Sept. 2009)***

Ans. There are following tests of concrete –

(i) Compaction factor test
(ii) Slump cone test
(iii) Crushing strength test.

(i) Compaction Factor Test – Compaction of concrete is the process of removal of the air bubbles which are entrapped in the concrete, to give maximum density to the concrete. This test is developed to estimate the workability of the concrete.

There are three vessels in this instrument. One is the cylindrical vessel, while others are hopper type. These are arranged one above the other like that, hopper 'B' is placed below hopper 'A', cylindrical vessel 'C' is placed below the hopper 'B', as shown in fig. 1.17. The vessel 'A' is filled with the sample of concrete. The hinged door which is provided at the bottom of vessel 'A' is opened out so that, the concrete falls in to hopper 'B'. After this, hinged door of the vessel 'B' is opened so that the concrete will fall in to the cylinder. The concrete of cylinder are now weighed let it to be W_1.

Now after removing the concrete the cylinder is again filled with the sample in 5 cm layers which is compacted by ramming and vibrating and then weighed let it to be W_2.

The compaction factor = W_1/W_2

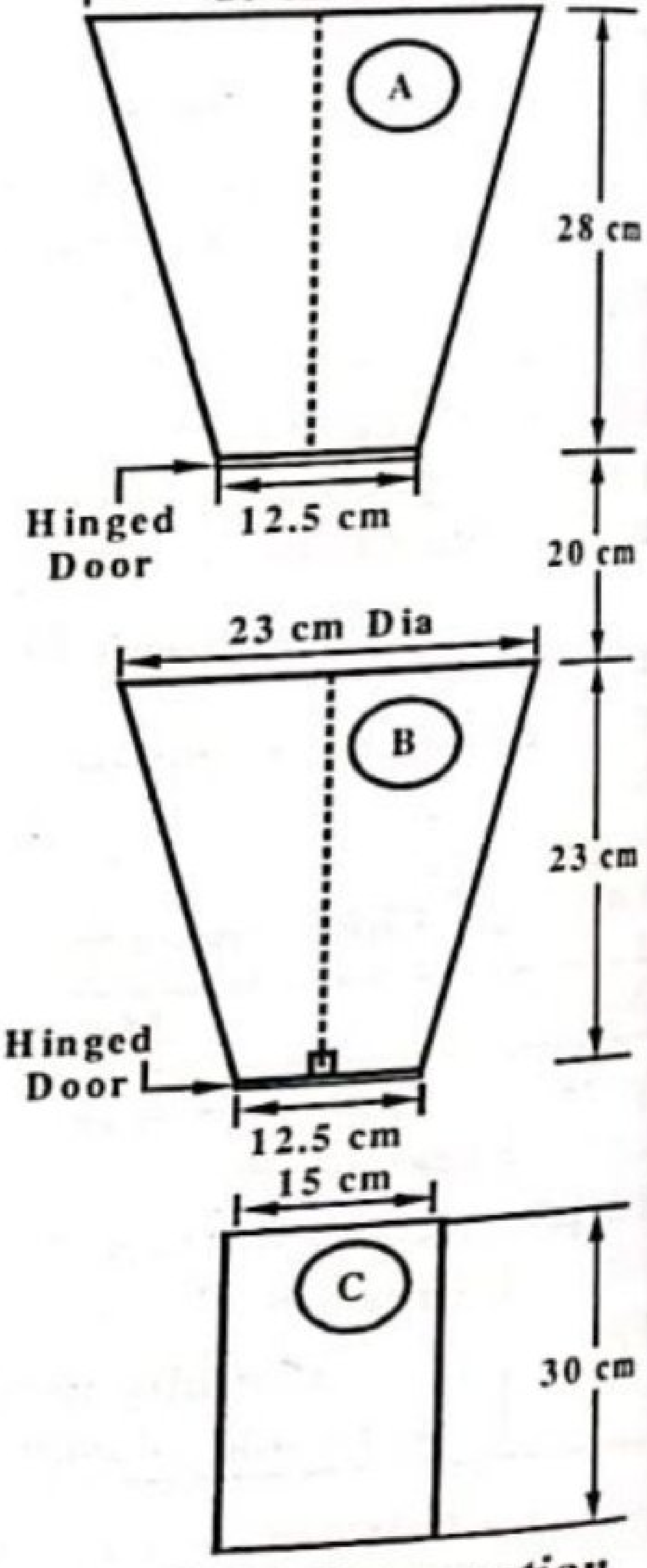


Fig. 1.17 Compaction Factor Test

The following conclusions are made based on the value of the compacting factor –

Value of Compacting Factor	*Standard of Workability*
0.95	Good
0.92	Medium
0.85	Low

(ii) Slump Cone Test – This test is used to find out the consistency of concrete. Consistency of concrete means the fluidity of concrete.

Concrete is filled in the standard slump cone which consists of a vessel whose shape is like a frustum of a cone, in four layers. Each layer is tamped by means of hammer 25 times.

Immediately after filling, the cone is lifted slowly and the unsupported concrete will slump. The decrease in the height of the highest part of the slumped concrete is called slump, as shown in fig. 1.18.

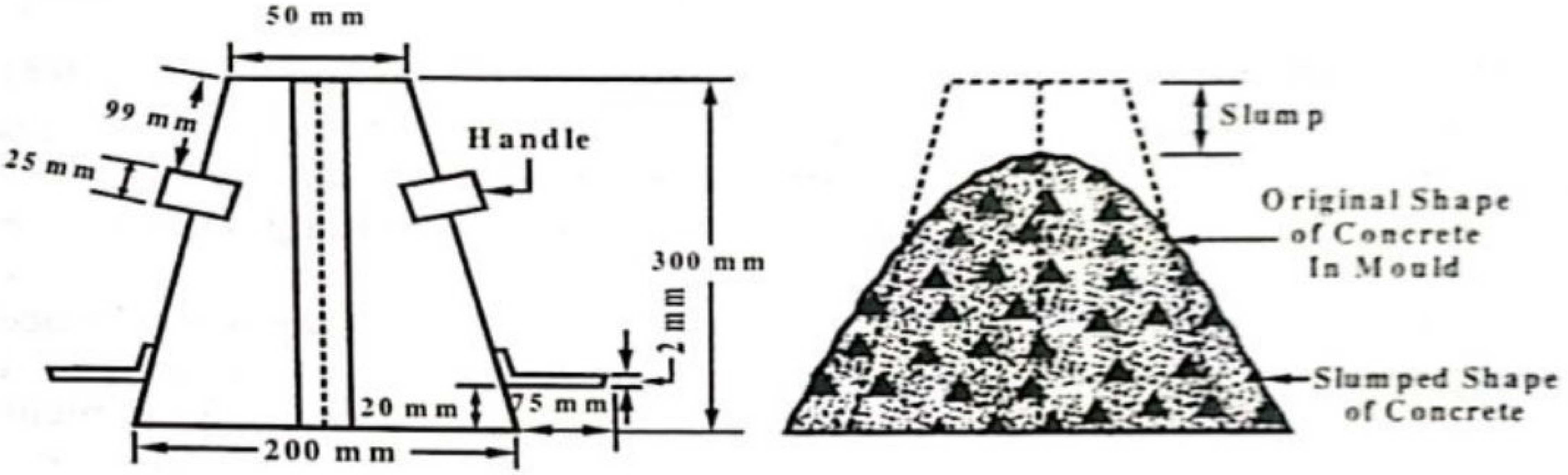

50 mm
99 mm
25 mm
Handle
300 mm
2 mm
20 mm
75 mm
200 mm
Slump
Original Shape of Concrete In Mould
Slumped Shape of Concrete

Fig. 1.18 Slump Cone Test

Q.66. What do you understand by the term workability of concrete ? Define and explain how we can detect workability. (R.G.P.V., Dec. 2017)

Ans. Refer Q.49 and Q.65 (i).

Q.67. Write short note on – Compressive strength test of cement concrete. (R.G.P.V., Nov./Dec. 2007)

Ans. Compressive strength test is performed on 15 × 15 × 15 cm cube. Metallic mould is used for casting concrete. Fresh concrete is filled in three layers in mould. Cubes are kept in wet room for whose temperature is about 27° C. After that curing is done in usual way.

Cube can be tested after 3, 7, 14 and 28 days. Cube is placed in compression testing machine and axial load is applied at a rate of 140 kg/cm^2. In actual, concrete is required sufficient time to gain strength. Usually 28 days strength is taken as full strength of concrete. Sometimes the strength of concrete may be required to be tested earlier, generally at 7 days.

Table 1.3 Minimum 7-day Strength of Concrete

Grade of Concrete	*Compressive Strength at 28 days (N/mm^2)*	*Compressive Strength at 7 days (N/mm^2)*
M-10	10	7
M-15	15	10
M-20	20	13.5
M-25	25	17
M-30	30	20

The minimum compressive strength at 7 days and maximum compressive strength at 28 days is given in table.

It is generally noted that two-third of full 28 days strength is attained in 7 days.

Q.68. Write short note on reinforced cement concrete (R.C.C.).
(R.G.P.V., April 2009, June 2009, 2010)
Or

Define R.C.C. ***(R.G.P.V., June 2016)***

Ans. R.C.C. is the combination of reinforcement, cement, aggregates and sand, in which reinforcement is provided for taking tensile stresses and combination of cement, aggregates and sand is provided for taking compressive stresses.

Concrete is very weak in tension but it is strong in compression. Hence cement concrete is reinforced by embedding steel in tensile zone as well as in some cases in compression zone also. It is known as reinforced cement concrete. Reinforced concrete is thus a rational union of concrete and steel combined to act jointly. The joint action of steel and concrete in a reinforced concrete section is dependent on the following important factors –

(i) Bond between concrete and steel
(ii) Absence of corrosion of steel bars embedded in the concrete
(iii) Practically equal thermal expansion of both concrete and steel.

Q.69. What is R.C.C. ? Describe in detail along with its preparation, properties and uses. (R.G.P.V., Jan./Feb. 2007, 2008, Sept. 2009, Dec. 2010)

Ans. **Reinforced Cement Concrete** – Refer of Q.68.

Preparation of R.C.C. – Following four materials are required for making R.C.C.–

(i) Cement (ii) Aggregates (iii) Steel (iv) Water.

(i) Cement – Refer Q.52 (i).

(ii) Aggregates – Refer Q.52 (ii).

(iii) Steel – The steel reinforcement is generally in the form of round bars of mild steel. The diameters of bars vary from 5 mm to 40 mm. Sometimes the square bars or twisted bars or ribbed-tor steel are used as steel reinforcement.

Following are the reason as to why mild steel has been adopted as reinforcing material –

(a) There is proper bond between cement concrete and steel. Hence, it enables concrete to transmit its stresses to steel.

(b) The coefficient of linear expansion of steel is almost the same as that of concrete. Hence no internal stresses are set up within reinforced concrete members due to rise or fall in temperature.

(c) Deformed or twisted bars which are made of mild steel have considerably high yield stress, tensile strength and bond strength.

(iv) Water – Refer Q.52 (iii).

Properties of R.C.C. –

(i) The co-efficient of linear expansion of concrete and steel are almost same. Therefore no internal stresses are developed in R.C.C. due to change in temperature.

(ii) The coating of cement on reinforcement protects it from corrosion.

(iii) Concrete transfers the stresses to steel, which it cannot resist itself.

(iv) R.C.C. member is fire resisting.

(v) It provides monolithic and rigid joints.

(vi) It is not affected by termites and vermins etc.

(vii) These member can be made to any desired shape.

(viii) These members are economical than steel members.

(ix) R.C.C. is a watertight material.

(x) R.C.C. is having less maintenance cost.

Uses of R.C.C. – Reinforced cement concrete is commonly used to construct the following elements –

(i) Slabs
(ii) Lintels
(iii) Beams
(iv) Columns
(v) Footings
(vi) Piles etc.

Q.70. Write down the advantages of R.C.C.

Ans. **Advantages of R.C.C. –**

(i) Concrete can be moulded to any shape and hence any architectural shape may be given to the structure.

(ii) R.C.C. ingredients are easily available.

(iii) Monolithic character of structure impart more rigidity to the structure.

(iv) It is economical in initial construction.

(v) Its maintenance cost is practically nil.

(vi) It is sufficiently water tight and impermeable if proper controls are exercised during mixing, proportioning, placing, consolidation and curing etc.

(vii) R.C.C. structures are completely fire resistant.

(viii) They are durable and not easily affected by atmospheric agencies.

Q.71. Write short note on prestressed concrete. (R.G.P.V., Dec. 2010)

Ans. In case of ordinary reinforced concrete which consists of concrete and mild steel, compressive stresses are borne by concrete while tensile stresses are borne by steel. The concrete surrounding steel reinforcement does not take tension as concrete is weak in tension. Thus only that portion of concrete, which lies above the neutral axis is considered to be useful in resisting compressive stress. This results in heavy section.

Prestressed concrete is basically concrete in which internal stresses of a suitable magnitude and distribution are introduced so that the pre-compressive stress in concrete will balance the tensile stress produced in concrete (surrounded steel) due to external loads. Due to this, the whole of the concrete can participate in resisting the external forces. In reinforced concrete members, the prestress is commonly introduced by tensioning the steel reinforcement.

Prestressed Material – Principal materials used in PSC are (i) High tensile steel and (ii) High strength concrete.

Ordinary mild steel wires are not useful because no pre stress will be left in wires after losses. The initial tensile strain in steel is reduced after tensioning by as much as 15 to 20% due to various losses.

Concrete used in PSC of good quality and of high strength. A well compacted dense concrete has less elastic strain and has less shrinkage plastic flow thus reducing the loss of prestress considerably.

Prestressed concrete may be classified into a number of ways, depending upon method of applying prestressing and purpose of structure. Some of these are given below –

(i) External or Internal Prestressing System – External prestressing is achieved by external reactions introduced through different support conditions.

(ii) Linear or Circular Prestressing – Linear prestressing is applied in straight members such as beams, slabs, piles etc. Circular prestressing is applied to circular structure such as tanks, pipes, silos etc. where prestressing tendons are would around circumference.

(iii) Pretensioning and Post Tensioning System – In pretensioning system, the tendons are pre stressed before the concrete is placed. In post tensioning system the member is concreted and a duct is formed in member either with a tube or with a metal sheet. When the concrete is sufficient hard, the tendons are tensioned and anchored to the concrete member of its ends.

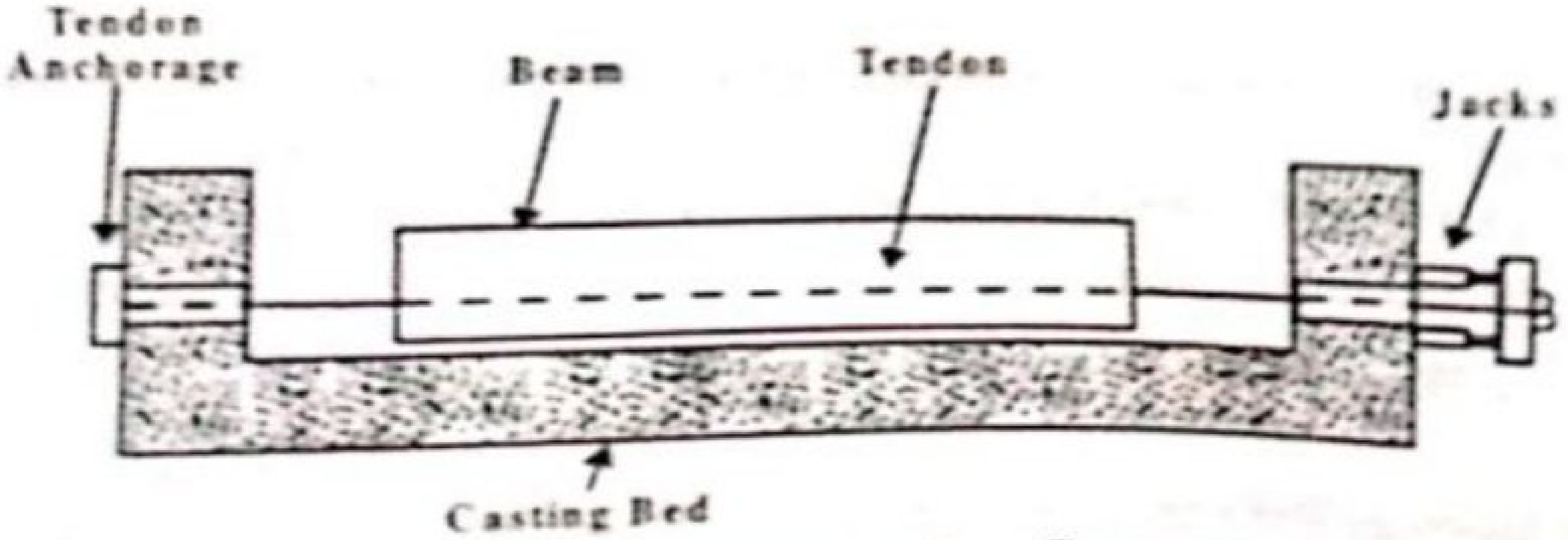


Fig. 1.19 Pretensioning System

(iv) Full Prestressing or Partial Prestressing – If there are no tensile stresses in concrete under working load, concrete is said to be prestressed. If some tensile stresses are produced in concrete under working load conditions. It is said to be partially prestressed.

Q.72. Write short note on ferrocement. ***(R.G.P.V., Dec. 2010)***

Ans. Ferrocement is considered as a highly versatile form of composite material made of cement mortar and layers of wire mesh or similar small diameter steel mesh closely bound together to create a stiff structural form. This material which is a special form of reinforced concrete exhibits a behaviour so different from conventional reinforced concrete in performance strength and potential application that it may be classed as a separate material. Dispersion of the fibers in the brittle matrix offer not only convenience and practical means of achieving improvements in many of the engineering properties of material such as fracture, tensile and flexural strength, toughness, fatigue resistance and impact resistance but also provide advantages in terms of fabrication of products and components.

According to **American Concrete Institute (ACI)** defines it as follows –

"Ferrocement is a type of thin wall reinforced concrete construction here usually cement is reinforced with layers of continuous and relatively small diameter mesh."

The basic idea behind this material is that concrete can undergo large strains in the neighbourhood of the reinforcement and the magnitude of strains depends on the distribution and subdivision of the reinforcement throughout the mass of concrete.

The wire meshes are usually 0 .5 to 1 mm in diameter and spaced at 5 to 25 mm apart and the volume of the mesh ranges from 1 to 8% of the total volume of the structural element. The thickness of ferrocement sections vary from 10 to 40 mm. The cover to the outer most layers of wires is usually 1.5 to 2 mm.

ELEMENTS OF BUILDING CONSTRUCTION

#***Q.73. Define elements of building construction. (R.G.P.V., June 2016)***

Or

What do you understand by elements of building ?

[R.G.P.V., June 2008 (N)]

Or

Explain the various elements of building construction.

(R.G.P.V., Dec. 2012)

Ans. There are various parts or elements of building, those are used for constructing a building.

(i) ***Foundation*** – It is the part of the building which is below the ground level. It support the structure and transmit the load of the structure to the soil.

(ii) ***Plinth*** – The structure between ground level and floor level is called plinth.

(iii) ***Superstructure*** –The structure above the plinth is called superstructure. It include wall, doors, windows, roofs and floors.

(iv) ***Masonry*** – Masonry is defined as an art of construction in which building units such as building stones cement, and sand or combination of all or some of these are arranged systematically to provide bonds and strength.

(v) ***Stone Masonry*** – Whenever stones are used in masonry they are called as stone masonry.

(vi) ***Brick Masonry*** – Whenever bricks are used in masonry they are called as brick masonry.

(vii) ***Wall*** – Walls are combination of bricks, stones, cement and sand, which inclosed or divide the space. They support the floors and roofs. They provide privacy and impart the protection against heat, cold, sun and rain.

(viii) ***Floors*** – These are the horizontal elements of building which divide a building into different levels.

(ix) ***Roofs*** – It is the upper most part of the building, which protect the building against rain, cold, sun, wind etc.

(x) ***Doors*** – Doors are the movable barriers. Those held in position by a door frame. These door frames are provided in the openings of the wall which provides the access to the building or rooms.

(xi) ***Windows*** – These are the opening in a wall of a building which provides natural lights, ventilation and vision.

(xii) ***Stairs*** – It is the sequence of steps which provides ascent and descent between the floors.

(xiii) ***Lintel*** – It is a horizontal member which is placed over an opening. It acts like a beam. It transfers the loads, acting over the openings, to the supporting walls.

(xiv) ***Chajja*** – It is a sloping or horizontal structure as over hang usually provided over opening on external walls to provide protection from sun and rain.

(xv) ***Footing*** – It is the lowermost part of the foundation, which is directly contact with the soil.

Q.74. Describe orientation. ***(R.G.P.V., Dec. 2008)***

Ans. Orientation means setting of plan of the building with reference to North, South, East and West directions. This provides an opportunity to user to enjoy sunshine and breeze when required and to avoid the same whenever not required. Sunshine is required in morning for kitchen. Hence kitchen should be placed on East side, Living room on North. The choice, however, depends on the climate of the place.

The orientation of the building is fixed by studying the sun diagram, indicating the path of the sun at particular place during the year.

The following suggestions will be helpful in orientation of a buildings in India –

(i) Place long walls towards North and South and short walls be in East and West direction. This will help to reduce the area exposed to the sun's rays and which will absorb little heat.

(ii) Provide verandah and balcony on East and West.

(iii) The sun is towards the south during the hottest part of the day. Then exposure on South side can be reduced by providing chajjas and sunbreaking devices on doors and windows to protect the building from the sun's rays.

(iv) The exposure of the sun should be reduced by proper orientation and by planting trees on sunside.

Q.75. What do you understand by utility of space in a building ? ***[R.G.P.V., June 2008 (N)]***

Or

Describe space utility. ***(R.G.P.V., Dec. 2008)***

Ans. It means to achieve maximum benefit from minimum size of a room. The rooms should look spacious which depends upon proportions of length, breadth and height. For roominess –

(i) Provide rectangular rooms than square rooms. The square room appears smaller than the rectangular room of the same area.

(ii) Length to breadth ratio should be 1.2 to 1.5:1

(iii) The rooms should have proper height. More height creates cave like effect and the room appears smaller.

(iv) Apply light colour to the room as it creates the effect of more space than dark colour.

Q.76. What do you understand by energy efficiency in building ? ***[R.G.P.V., June 2008 (N)]***

Or

Describe energy efficiency. ***(R.G.P.V., Dec. 2008)***

Or

Write short note on energy efficiency in planning of building.
[R.G.P.V., Dec. 2004, June 2008 (O), 2009]

Ans. A building is said to be good only when it is functionally efficient for energy. A building should be planned in such a manner so that, it gives maximum energy efficiency or it gives maximum day lighting, ventilation and heat insulation.

In short, energy efficiency means maximum use of day lighting, ventilation and heat insulation in the building with fulfilment of its functional requirements. If building has proper day lighting and ventilation and good heat insulation then it saves the energy in term of reduction in the consumption of electricity and fuel.

The following points has to be always keep in mind while planning for building –

(i) If building has good heat insulations then it reduces the fuel consumption in winter and load on air-conditioning equipment during summer.

(ii) Thicker exterior walls provide insulation against heat and cold.

(iii) The proper orientation of building helps in achieving heat insulation requirements.

(iv) The sun of shading devices such as projecting roofs, chajjas, trees etc. help in achieving heat insulation requirements.

(v) The building should have windows to fulfil day-lighting requirements.

(vi) The light in the building should come from right direction.

(vii) The building should have good ventilation provisions.

Q.77. Discuss methods of making a factory building "energy efficient".
(R.G.P.V., Dec. 2003, Feb. 2005)

Ans. Whenever we are planning for a factory building we should keep following points in our mind for making factory building "energy efficient".

(i) Orientation of building should be such that, it gets maximum light and ventilation.

(ii) North light trusses should be provided to get maximum light.

(iii) Height of the shed should be more to maintain the temperature in the shed.

(iv) Factory building should have good ventilation provisions.

(v) The factory building should be provided with sun shading devices such as projecting roofs, trees etc.

(vi) The position of furnace (elements producing heat) should be located far away from other part of building.

(vii) The openings should be provided at higher level in the wall to remove heat from shed.

FOUNDATIONS, CONVENTIONAL SPREAD FOOTINGS, R. C. C. FOOTINGS

Q.78. What do you understand by term foundation and superstructure?
[R.G.P.V., June 2007, 2008(N)]

Ans. Every building or structure consists of two parts, namely foundations and superstructures.

The lowest part of the building, which is located below ground level and which transmit the loads of the structure to the ground are known as foundations. The ground on which the foundation rests is called as foundation bed. The foundation bed ultimately bears the load of the structure. The lowermost portion of the foundation which is in direct contact with the subsoil is called the footing.

The uppermost part of the building, which is above ground level is called as superstructure. The portion of the structure between the surface of the ground and surface of the floor is known as the plinth.

The basic function of a foundation is to transfer the dead loads, live loads and other loads to the subsoil. Thus for any structure, foundation forms the most important part. As foundation remains below the ground level, the signs of failure of foundations are not noticed till the structure is seriously affected. It becomes therefore be designed carefully to avoid their failures.

The foundations serves the following purposes –

(i) Foundations distribute the loads of the superstructure to a larger area so as the intensity of the load at its base does not exceeds the safe bearing capacity of the subsoil.

(ii) Foundations distribute the uneven load of the superstructure to the subsoil evenly.

(iii) Foundation support the structures.

(iv) It provides the safety to the structure against undermining or scouring due to animals, flood water, etc.

(v) It provides levelled and hard surface to the superstructure, over which superstructure can be built.

(vi) Foundation gives lateral stability to the structure against various horizontal forces such as wind, rain earthquake, etc.

Q.79. Discuss the essential requirements of a good foundation.

Ans. A good foundation should fulfil following requirements –

(i) The good foundation should able to wear dead and live load.

(ii) The good foundation should be taken sufficiently deep so as to reach for hard strata.

(iii) The base of the foundation should be rigid so that differential settlements are minimised.

(iv) The foundation should transfer the load of the superstructure in such a way so that pressure on subsoil will not cause settlement.

(v) The foundations should be so located that its performance may not be affected due to any unexpected future influence.

(vi) The area of the footing should be such larger, so as the intensity of the load at its base does not exceed the safe bearing capacity of the subsoil.

Q.80. Differentiate between footing and foundation.

(R.G.P.V., June 2013)

Ans. The footing lies on the ground around the base of the structure. The foundation can go way below with pilings deep into the ground. We can say that the footing is the part of foundation which transfers the load directly to the soil and foundation is the part of structure below the plinth level including the footing while footing is the part which is below the ground level.

Q.81. What is bearing capacity of soil ? What is its significance in construction ? ***(R.G.P.V., June 2007, 2010)***

Or

Describe how bearing capacity of a soil is improved and how it is determined in field ? ***(R.G.P.V., Nov./Dec. 2007)***

Ans. Bearing capacity of soil is the maximum load per unit area which the soil can resist safely without displacement. By dividing the bearing capacity of soil by factor of safety we will get safe bearing capacity of soil.

$$\text{Bearing capacity of soil} = \frac{\text{Maximum load coming on base of foundation}}{\text{Area of footing}}$$

$$\text{Safe bearing capacity} = \frac{\text{Bearing capacity of soil}}{\text{Factor of safety}}$$

Following points should be noted in connection with the bearing power of soil –

(i) The difference between the two terms, namely the maximum safe bearing capacity of soil and the allowable bearing pressure on soil should be noted.

The term maximum ***safe bearing capacity of soil*** is used to indicate the maximum pressure that a soil can bear without any risk of shear failure only, irrespective of any settlement that may occur.

The term allowable bearing pressure on soil is used to indicate the maximum pressure which can be exerted on a soil while taking into account shear failure, settlement and the ability of structure to resist settlement. Thus its value will depend on the nature of ground and the type of building.

The maximum safe bearing capacity of soil is generally more than the allowable bearing pressure on soil.

(ii) The term net pressure intensity is used to indicate the excess pressure or the difference in the intensities of the gross pressure after the construction of the structure and the original overburden pressure.

Q.82. Explain various types of foundations. *(R.G.P.V., Dec. 2016)*

Or

Describe the types of the footing. *(R.G.P.V., June/July 2006)*

Or

What are various types of foundations ? Give details of any two.
(R.G.P.V., Sept. 2009, Feb. 2010)

Ans. The foundations can be broadly classified into two categories –

(i) Shallow foundation (ii) Deep foundation.

(i) Shallow Foundation – Shallow foundations are made by making open excavations. They are the foundations commonly used in building industry. These foundations are practicable up to the depth of 3 m to 4 m, and is generally convenient above the water table. As these foundations are construct at reasonable shallow depth so as these are called as shallow foundations. They are also called as open foundations.

There are various types of shallow foundations as follows –

(a) Wall footing
(b) Isolated footing or column footing
(c) Combined footing
(d) Strap footing or cantilever footing
(e) Continuous footing
(f) Inverted arch footing
(g) Raft foundation
(h) Grillage footing.

(a) Wall Footing – These footings can be either simple or stepped. Simple footings are used to carry light loads, whereas stepped footings are used to carry heavy loads. Simple footing has only one projection on either side of the wall whereas stepped footings have numbers of projection on either side of the wall.

The base course of these footings can be concrete or entirely of one material. The width of concrete base should be atleast equal to twice the width of wall. The depth of concrete bed should be atleast equal to the projection. Generally, the projection provided in the footing is kept as 15 cm. on either sides.

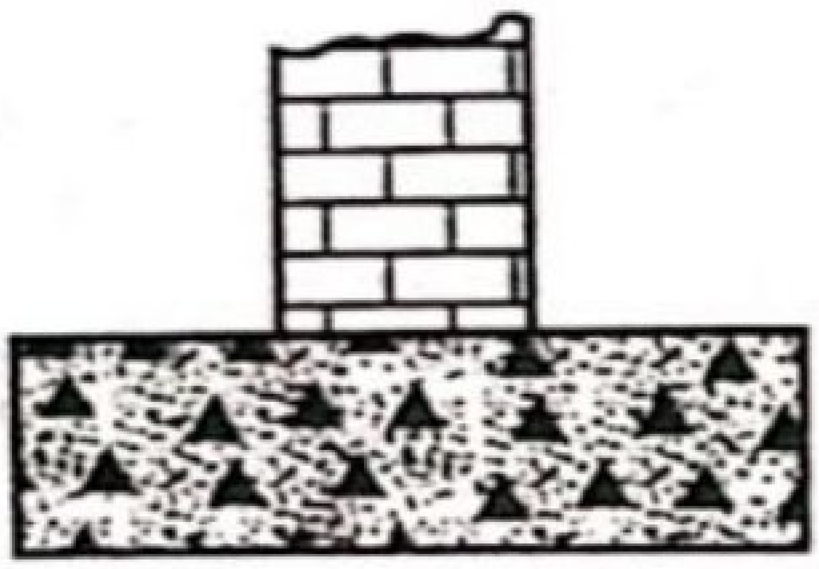


Fig. 1.20 Simple Wall Footing

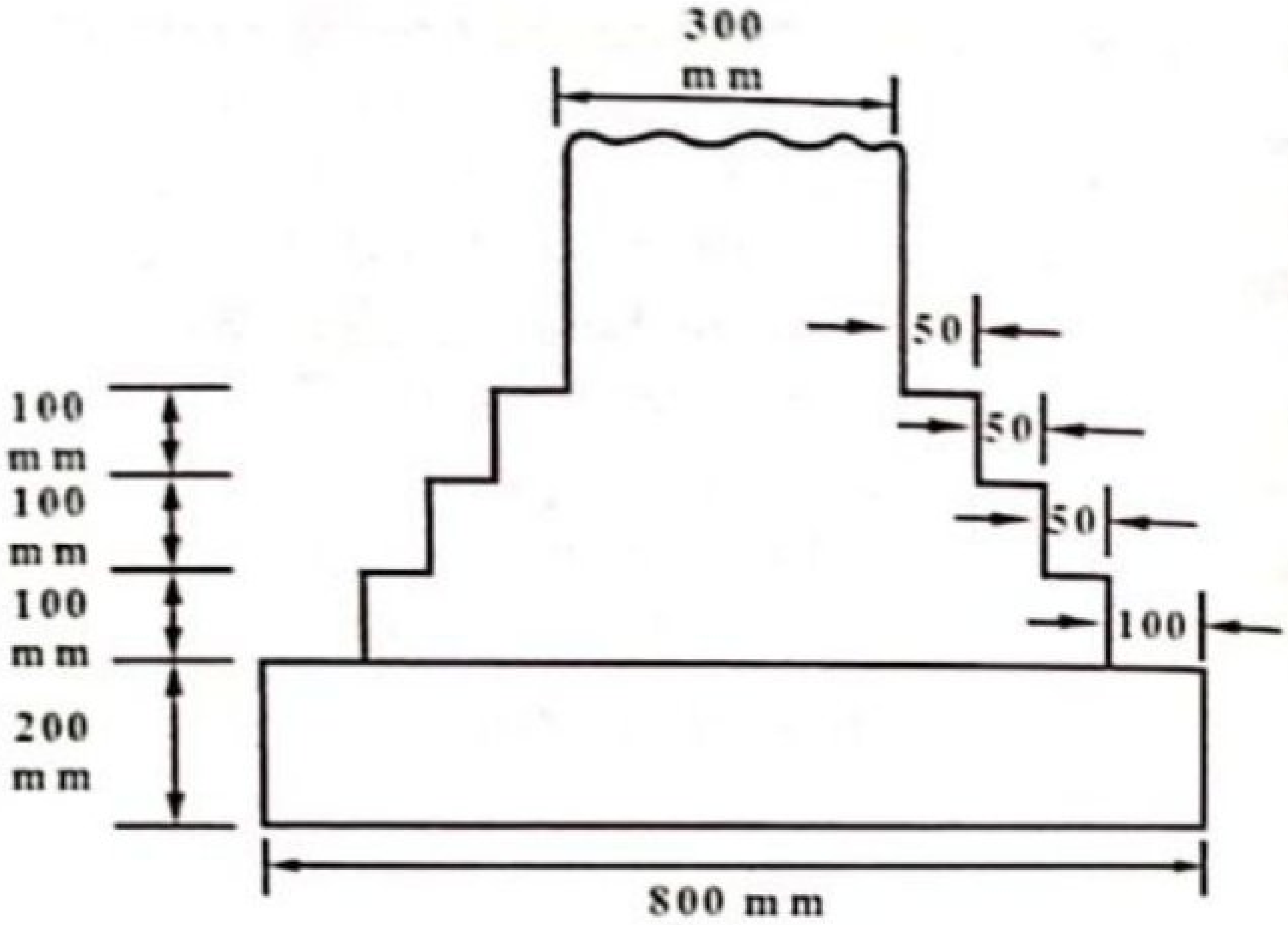
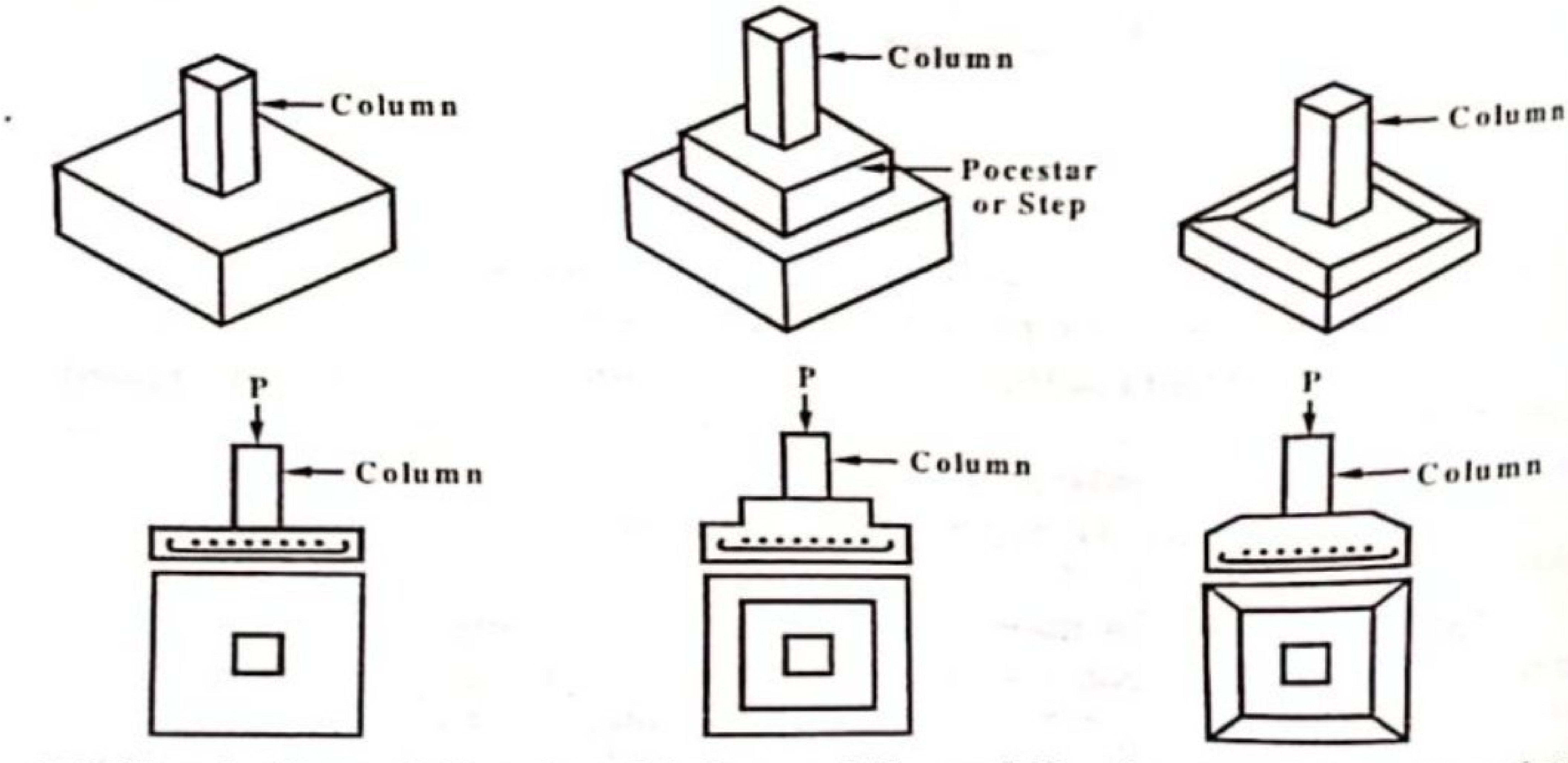


Fig. 1.21 Stepped Wall Footing

(b) Isolated Footing or Column Footing – They are used to support individual columns. They can be either of stepped type or have projections in the concrete base. In case of heavy loaded columns, steel reinforcement is provided in both the directions in concrete bed. Generally, 15 cm offset is provided on all sides of concrete bed. In case of brick masonry columns, an offset of 5 cm is provided on all the four sides in regular layers. The footing of concrete columns may be a slab, stepped or sloped type. See fig. 1.22.



(a) Simple Spread Footing (b) Stepped Spread Footing (c) Sloped Footing

Fig. 1.22 Types of Column Footings

(c) Combined Footing – A combined footing supports two or more columns in a row. The combined footing can be rectangular in shape if both the columns carry equal loads, or can be trapezoidal if there are space limitations and they carry unequal loads (See fig. 1.23). Generally, they are constructed of reinforced concrete. In the design of footings, the footing is assumed to be rigid and resting on a homogeneous soil. The location of centre of gravity of column loads and the centroid of the footing should coincide. The maximum bending moment is taken as the design value for the reinforced concrete footing and should be checked for maximum shear and bend, etc.

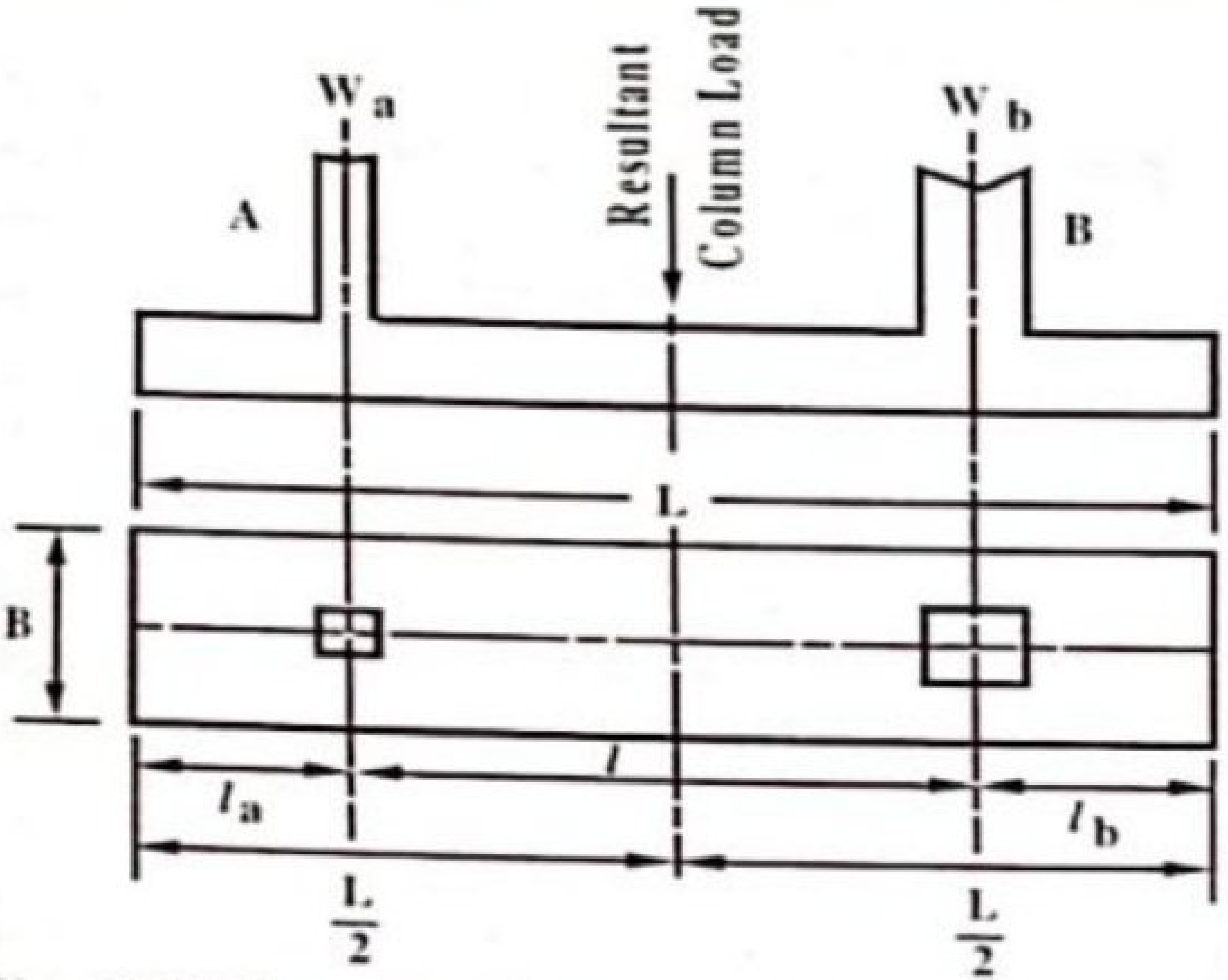


Fig. 1.23 Rectangular Combined Footing

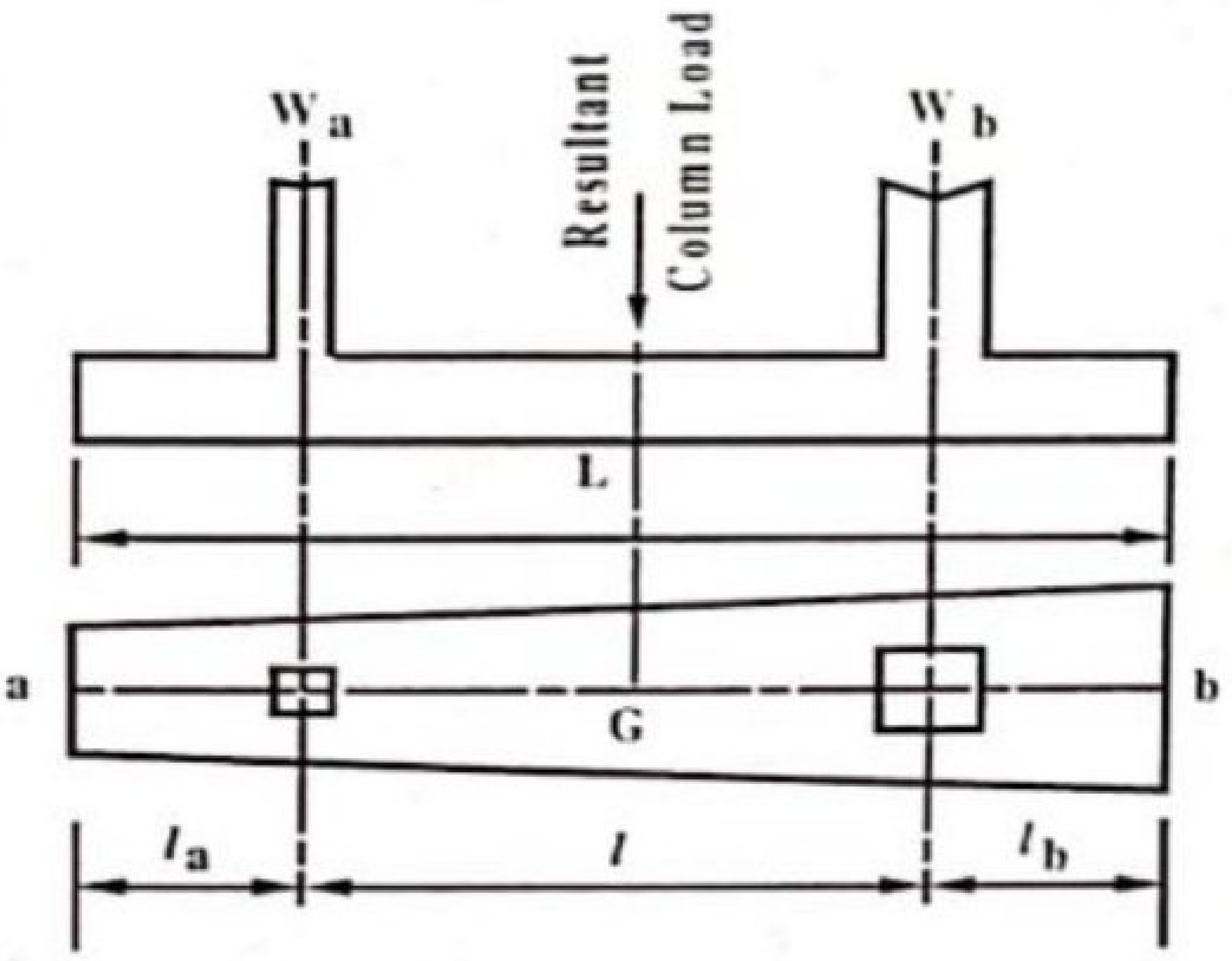
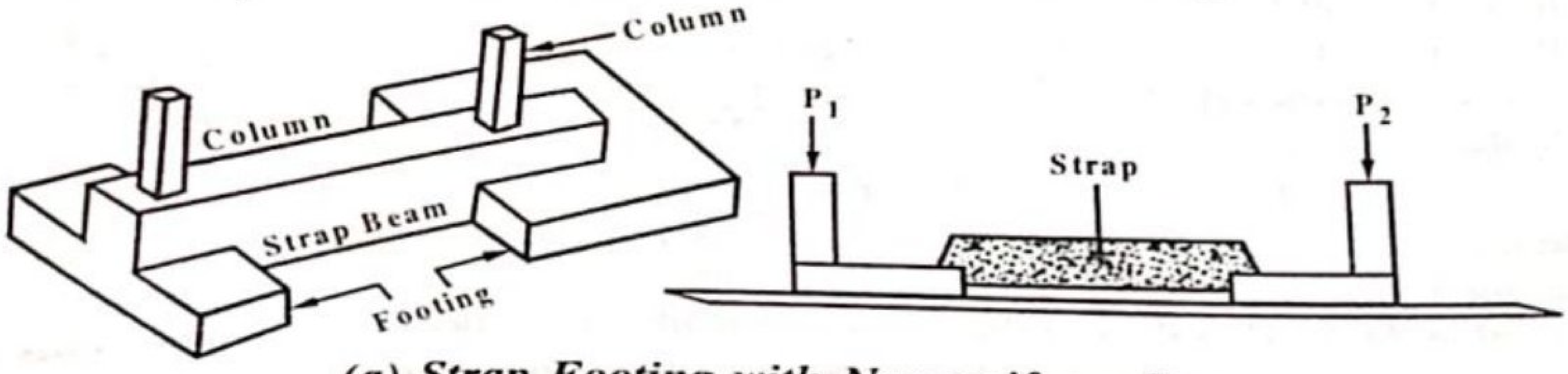


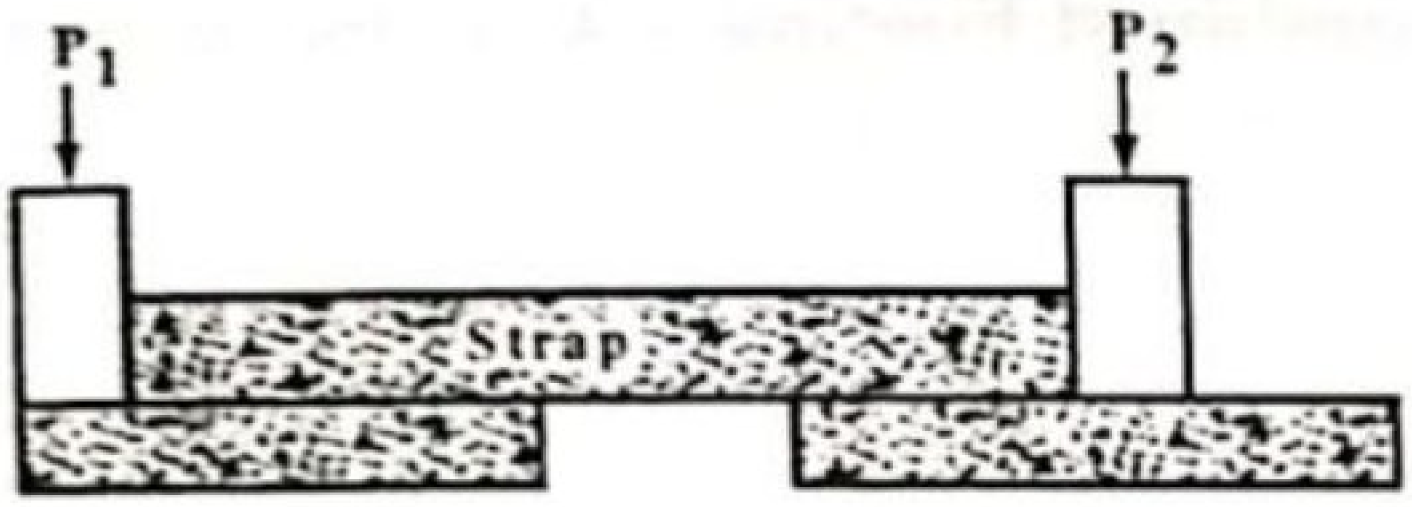
Fig. 1.24 Trapezoidal Combined Footing

(d) Strap or Cantilever Footing – Strap footing consists of two or more individual footings connected by a beam called a strap. It is also sometimes called as cantilever footing or pump handle foundation. See fig. 1.25.

This type of footing may be used where the distance between the columns is so great that a combined trapezoidal footing becomes quite narrow with high bending moments. The strap beam does not remain in contact with the soil; so a strap does not transfer any pressure to the soil. However, because the strap is infinitely stiff, hence it serves to transfer column loads on to the soil with equal and uniform soil pressure under both footings.



(a) Strap Footing with Non-uniform Strap



(b) Cantilever Footing with Uniform Strap

Fig. 1.25 Strap or Cantilever Footing

(e) Continuous Footing – This is shown in fig. 1.26. In this single continuous R.C.C. slab is provided as foundation for more than two columns in row. The resultant of the column loads W_1, W_2, W_3 must pass through the centroid of the footing in plan. This type of foundation is suitable in earthquake prone area and also prevents differential settlement.

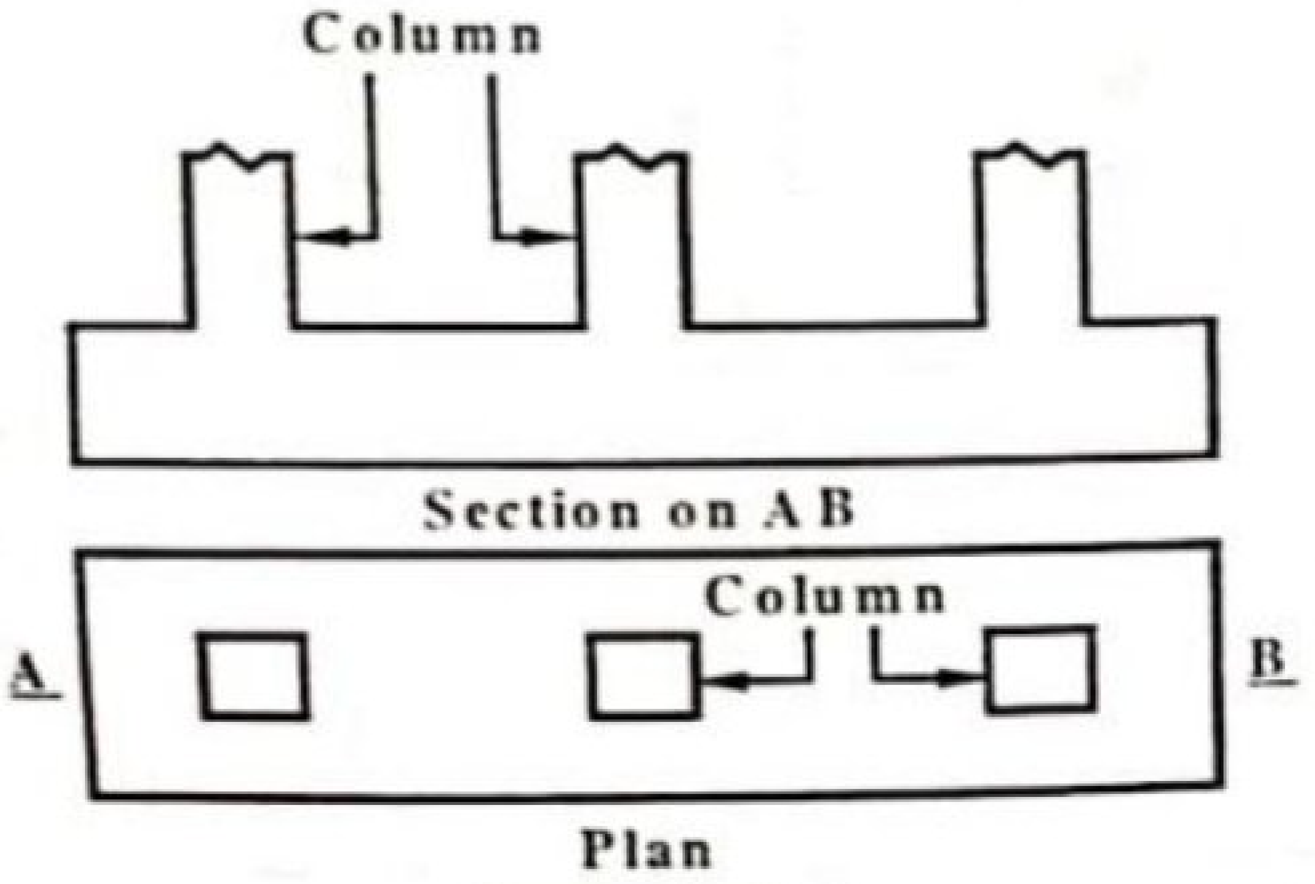


Fig. 1.26

(f) Inverted Arch Footing – Inverted arch footing is not a common type of foundation. This type of foundation is used in places where the bearing capacity of the soil is very poor and load of the structure is concentrated over the walls and deep excavations are not possible. In this case, arches are constructed between the two walls of the base. The walls must be sufficiently thick and strong to withstand the outward horizontal thrust caused by the arch action. Fig. 1.27 shows an inverted arch footing.

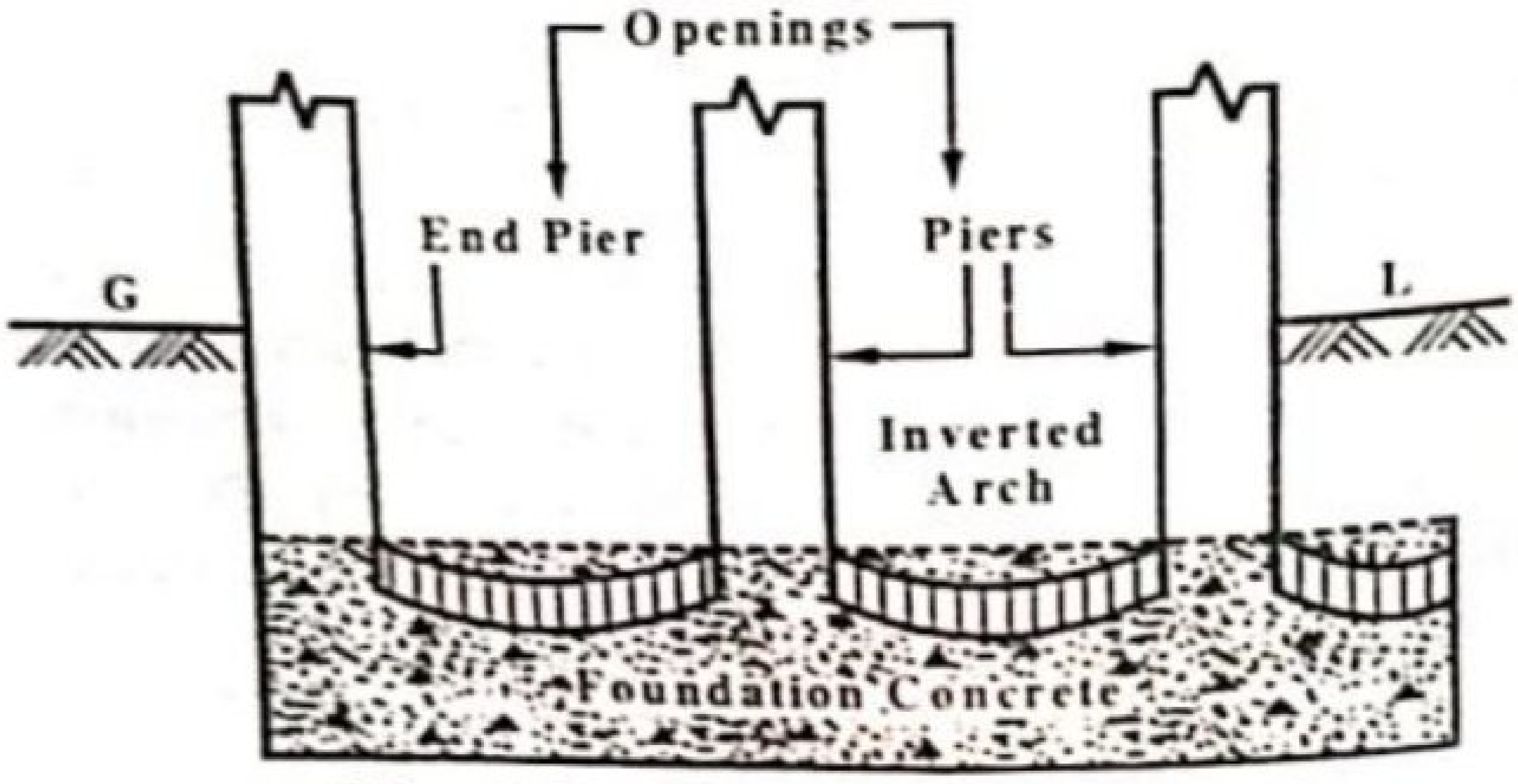


Fig. 1.27 Inverted Arch Footing

(g) Raft Foundation – Raft foundation is a combined footing that covers the entire area beneath a structure and supports all the walls and columns. In this foundation an R.C.C. slab with beam or without beam of suitable thickness with suitable reinforcement is provided. Over which walls and columns are constructed. This type of foundation is more useful whenever the load coming on the soil is practically uniform or soil is of yielding nature or where soil is tend to cause differential settlement or spread footing would cover more than half the area of the construction.

The design of raft foundation requires careful attention. Fig. 1.28 shows an raft foundation.

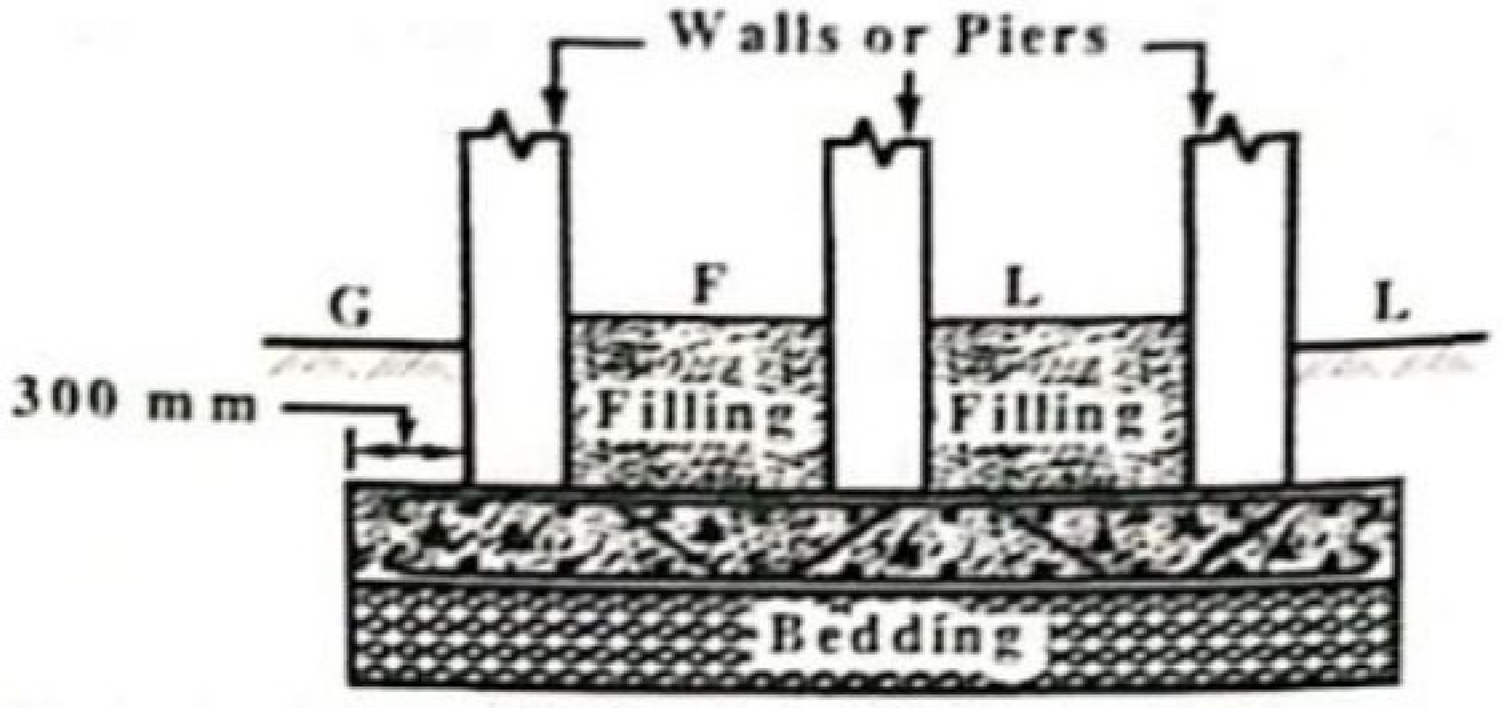


Fig. 1.28 Raft Foundation

(h) Grillage Footing – A grillage footing is used to transmit heavy loads from steel columns to the soils having low bearing power. This type of arrangement avoids deep excavations and provides necessary area at the base to reduce the intensity of pressure. Grillage footing is made up of rolled steel joists known as grillage beams provided in single or double tiers. In double tier arrangement, the top tier is laid perpendicular to the bottom one. The grillage beams of each tier are held in position by 20 mm dia spacer bars or 25 mm dia pipe separators. Generally, a minimum clearance of 8 cm is kept between the grillage beams so as to provide facility for placing concrete. However, the distance between the flanges of grillage beams should not be more than one and a half to two times the flange width so that the concrete filling acts monolithically with the beam. A minimum cover of 10 cm is provided on the outer sides of the external beam as well as above the upper flange of the top tier. In case of lower beams, the concrete cover under the beam should be more than 15 to 20 cm (see fig. 1.29). The concrete filling keeps the joists in position and prevents them from corrosion.

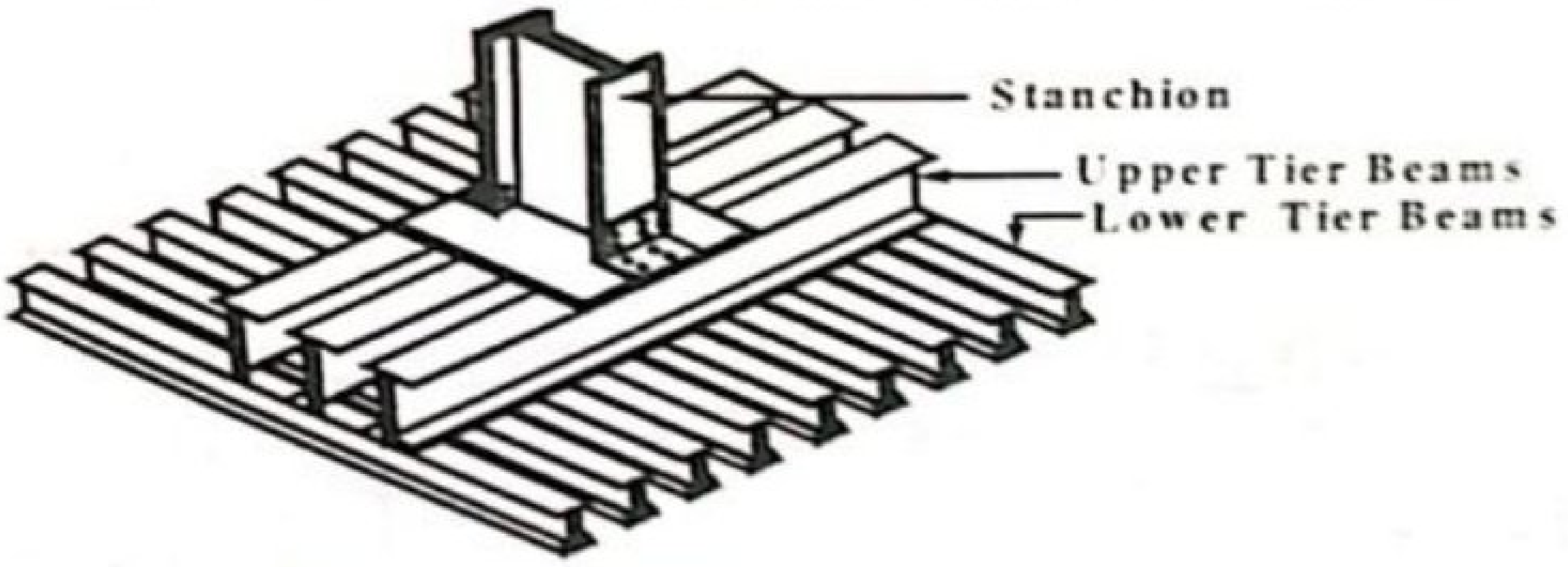


Fig. 1.29 Grillage Foundation

If the foundation soil is not stiff and there is plenty of water with springs, then sides are protected by shorings. The water is removed by pumping to provide working space.

(ii) Deep Foundation – Deep foundations are foundations which transmit the load of a structure to strong soil beds or rock beds available at great depth.

When the soil at or near the ground surface is not capable of supporting a structure, deep foundations are required to transfer the loads to deeper strata.

Deep foundations are of following types –

(i) Pile foundation
(ii) Pier foundation
(iii) Caisson or well foundation.

Q.83. What is slump ? Also explain different types of foundation.
(R.G.P.V., Dec. 2015)

Ans. Refer Q.65 (ii) and Q.82.

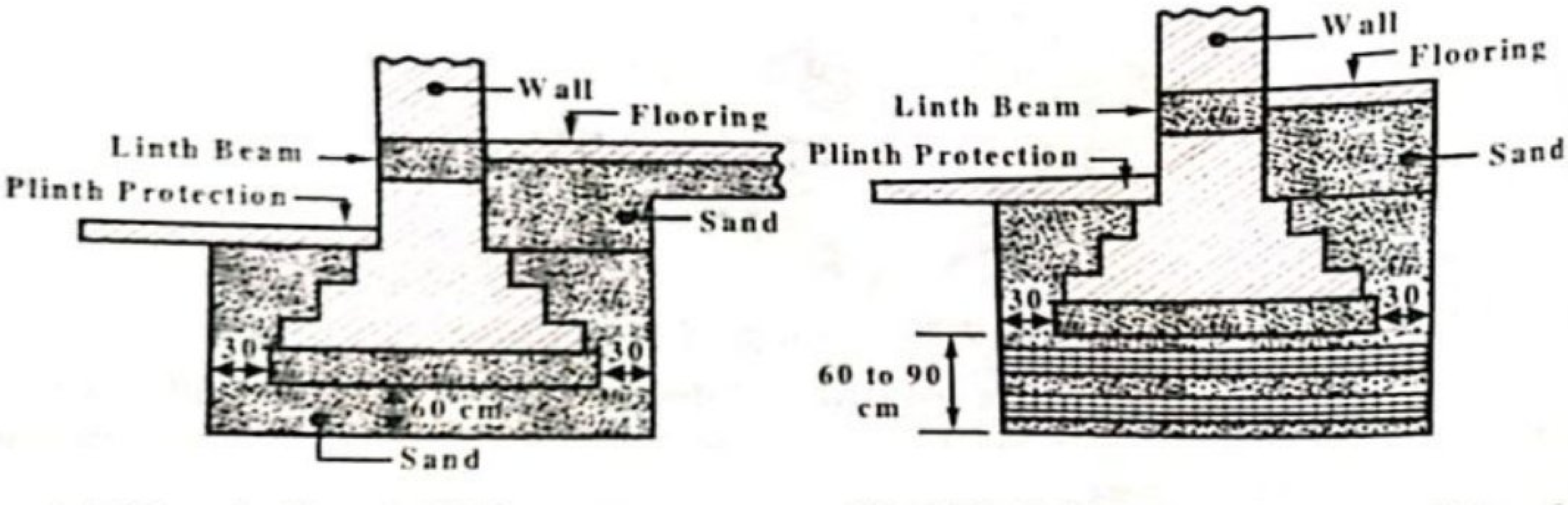
Q.84. What are the functions of foundation in building ? What types of foundation would you suggest for black cotton soil ? Explain with the help of sketch. ***(R.G.P.V., June 2011)***

Ans. **Functions of Foundation in Building** – Refer Q.78.

Types of Foundation in Black Cotton Soils – Foundation in black cotton soils may be of the following types –

(i) Strip or pad foundation
(ii) Pier foundation
(iii) Under-reamed pile foundation.

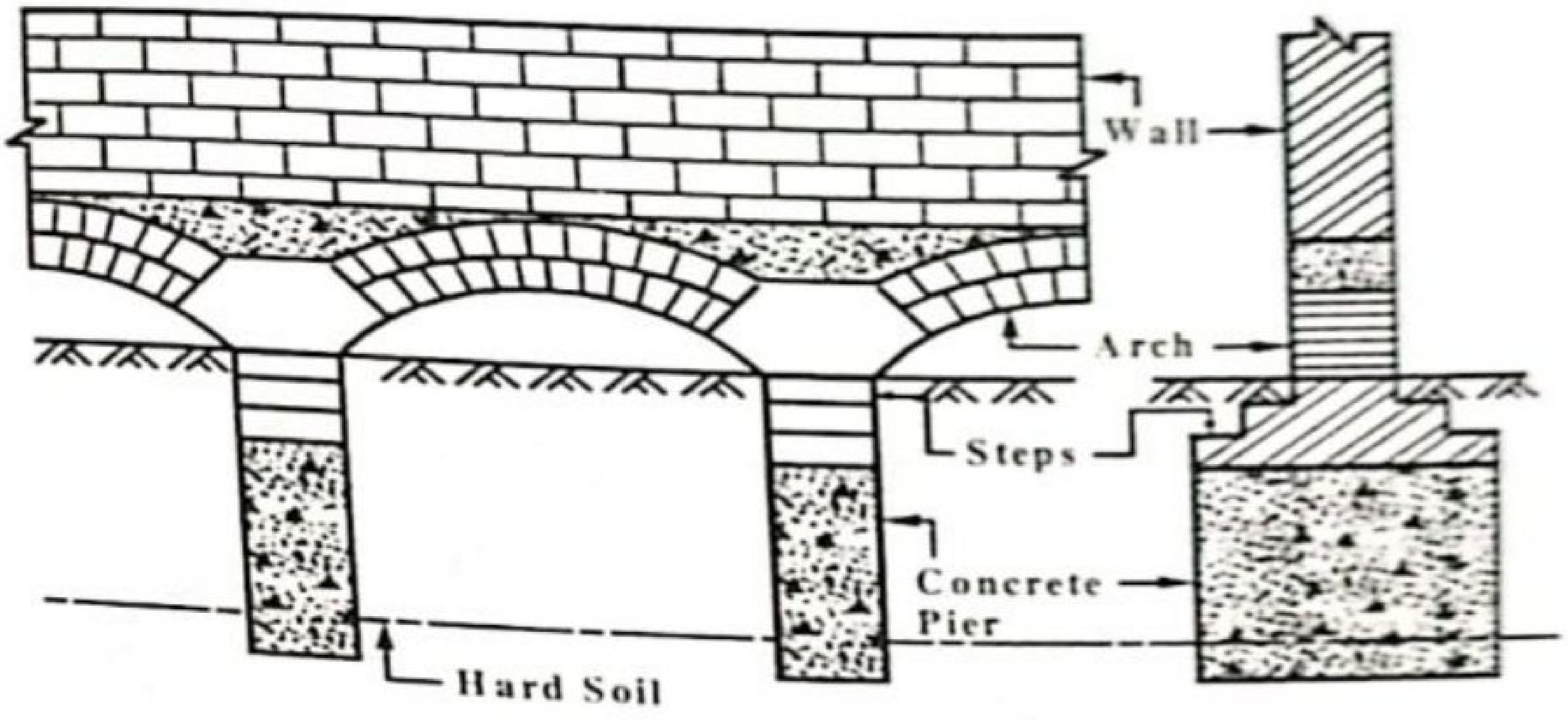
(i) Strip or Pad Foundation – For medium loads, strip foundation (for walls) and pad foundation (for columns) may be provided, along with special design features. Fig. 1.30 shows some typical sections of shallow footings suitable for black cotton and other expansive soils.



(a) Simple Sand-fill Structure ***(b) Fill of Alternate Layers of Sand and Mooram***

Fig. 1.30

(ii) Pier Foundation with Arches – Fig. 1.31 shows a typical pier foundation for a wall carring heavy loads. Piers are dug at regular interval and filled with cement concrete. The piers may rest on good bearing strata. These piers are be connected by concrete or masonry arch, over which the wall may constructed. If required, a concrete beam may be provided over the arch if the arch is constructed of masonry. The arches are constructed with a gap above the ground level. This gap would permit free vertical movement of soil during swelling and shrinkage operations.



(a) L-Section *(b) Cross-Section*

Fig. 1.31 Pier Foundations with Arch

(iii) Under-reamed Pile Foundation – An under-reamed pile is a pile of shallow depth (1 to 6 m) having one bulb at its lower end. If this bulb is taken or provided at a level lower than the critical depth of moisture movement in expansive soils, the foundation will be anchored to the ground and it would not move with the movement (i.e. swelling and shrinkage) of the soil. These piles may vary from 15 cm dia. to 50 cm dia., and are suitably spaced. Special under-reaming tools are available with the help of which these may be bored at site, and then concreted. They are nominally reinforced to take tensile stresses.

The piles spacing may vary betwee.ı 2 to 4 m. The piles are connected by a rigid capping beam, suitably reinforced, over which the wall is constructed. The capping beam is kept 8 to 12 cm above the ground level, so as to provide air gap to accommodate the soil movements without adversely affecting the superstructure. Experience has shown that the buildings constructed on under-reamed piles in expansive soils are free from distress normally caused in these soils (See fig. 1.32).

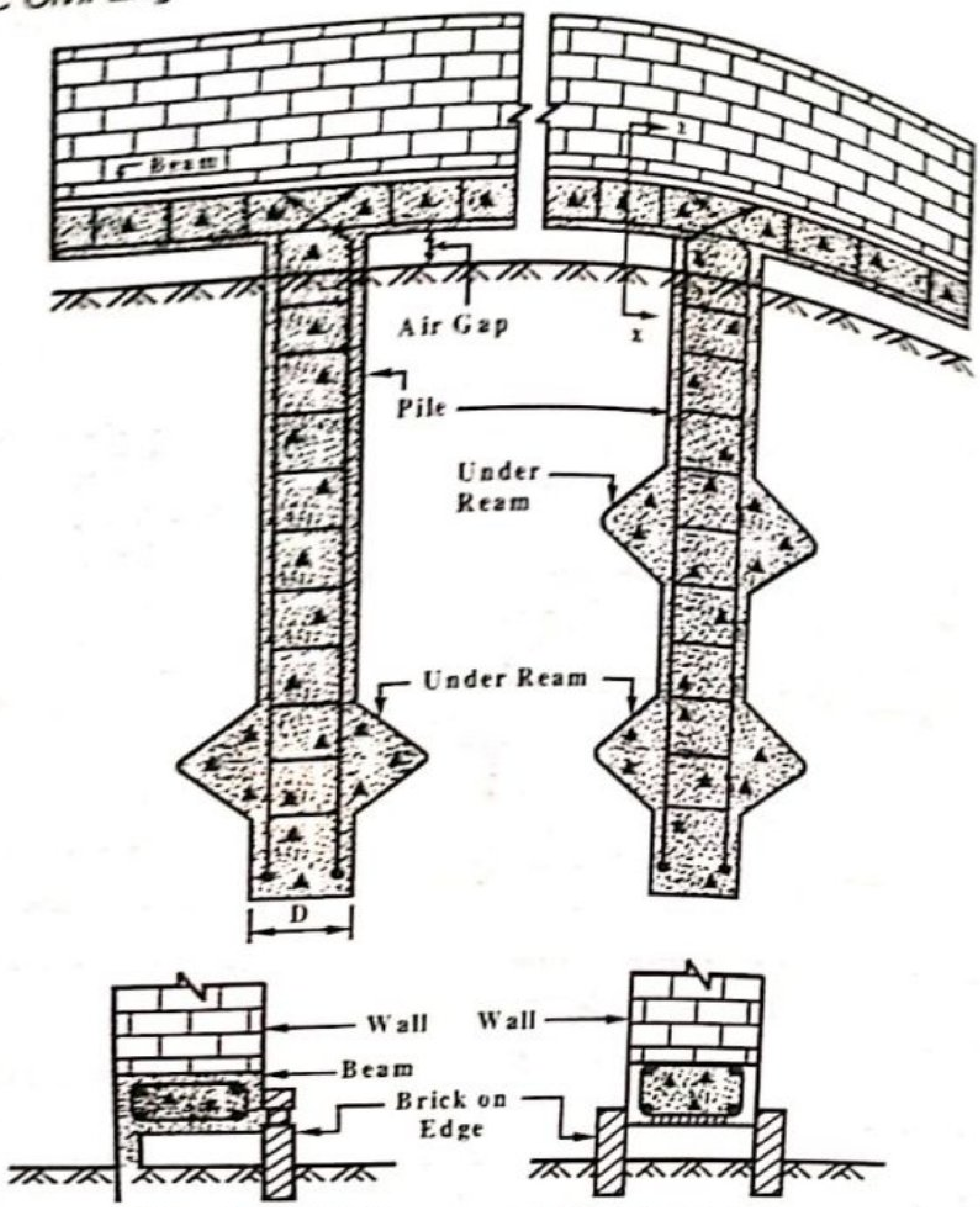


Fig. 1.32 Under-reamed Pile Foundation

Q.85. What is the importance of foundation in a building ? With the help of neat sketches explain about the constructional features of the under-reamed pile foundation. ***(R.G.P.V., Dec. 2011)***

Ans. Importance of Foundation in Building – Refer Q.78.

Under-reamed Pile Foundation – Refer Q.84 (iii).

Q.86. Explain R.C.C. footing with neat sketch. (R.G.P.V., Jan./Feb. 2008)

Ans. It is the type of the footing in which we have used reinforcement with concrete. This type of footing is provided where concrete columns are used. The shape of footing may be square, circular, or rectangular. The footing may be stepped or slopped. A slab of concrete provided as a bed slab with reinforcement in both the directions with proper cover, then vertical upward reinforcement are provided for column. Afterwards slopping or stepped portion is prepared with concrete for depth twice of depth of the slab. Fig. 1.33 and fig. 1.34 shows the stepped R.C.C. footing and slopped R.C.C. footing.

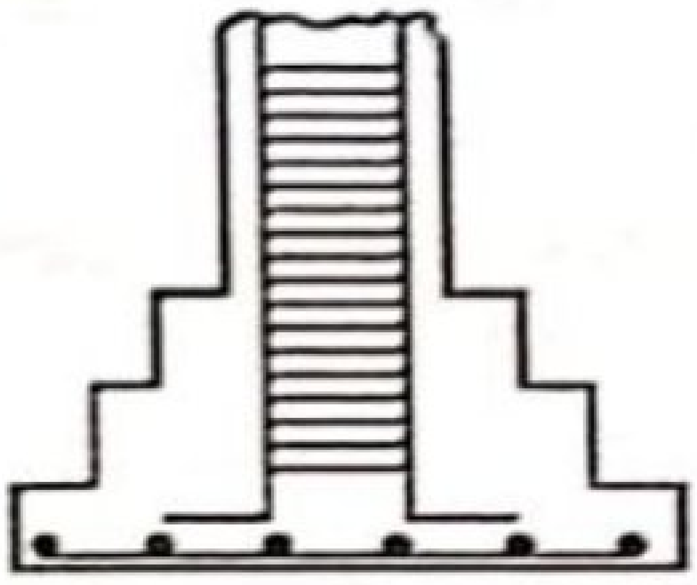


Fig. 1.33 Stepped R.C.C. Footing

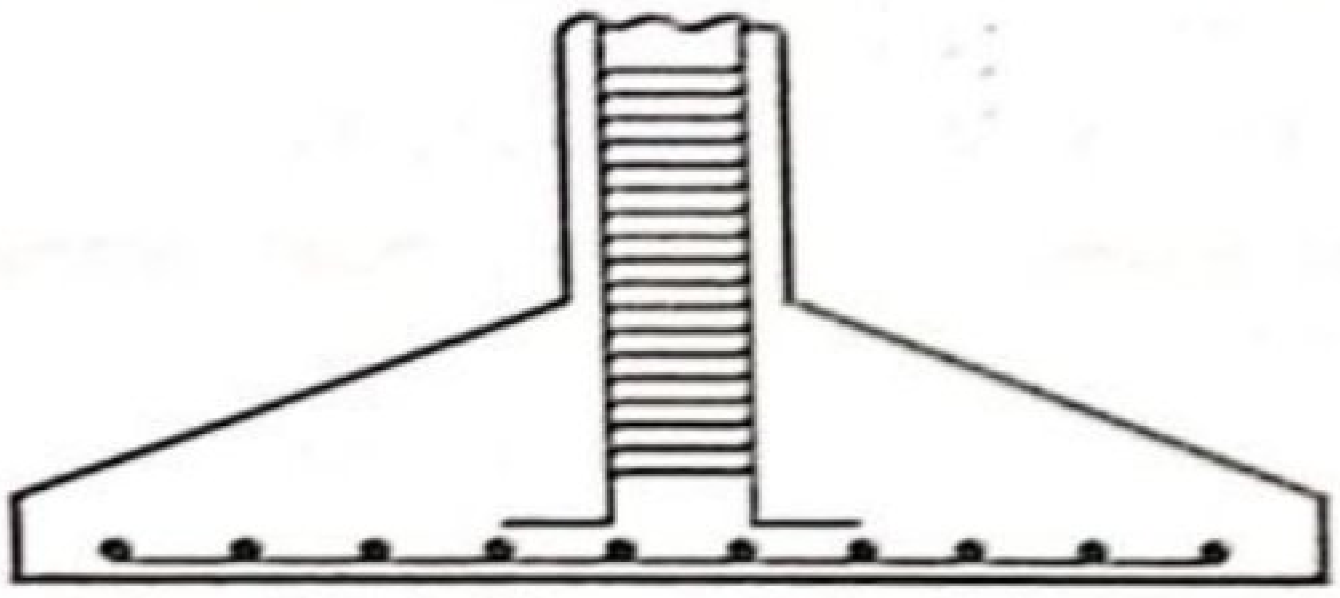


Fig. 1.34 Slopped R.C.C. Footing

Q.87. Draw a neat labelled diagram of R.C.C. footing for a circular column of 300 mm dia. ***(R.G.P.V., June 2012)***

Ans.

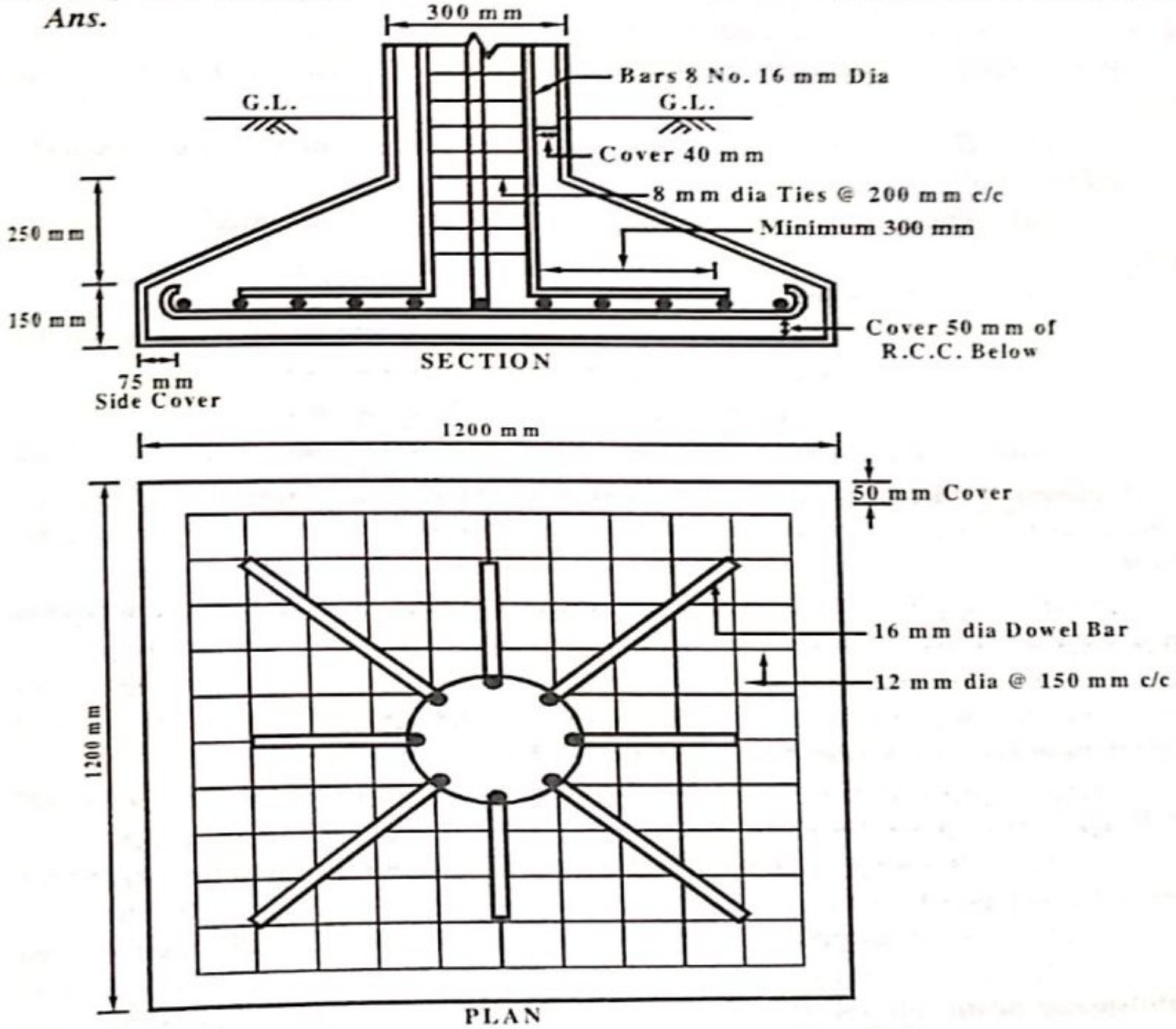


Fig. 1.35 R.C.C. Footing for Circular Column

Q.88. What are the objectives for providing foundation in the building ? Draw a neat sketch of RCC circular column footing with details of column and pedestal. ***(R.G.P.V., June 2014)***

Ans. Refer Q.78 and Q.87.

BRICK MASONRY WALLS, PLASTERING AND POINTING

Q.89. Explain brick masonry walls. State the general principles to be observed in brick masonry construction. ***(R.G.P.V., Dec. 2004)***

***Ans.* Brick Masonry –** Brick masonry is made up of brick units bonded together with mortar. The strength of brick masonry depends upon the quality of brick, quality of mortar and method of bonding used.

Brick masonry is preferred over other types of masonry due to following reasons –

(i) Bricks are in uniform shape and size, hence they can be laid in any definite pattern.

(ii) They can be easily handled due to light in weight and small in size.

(iii) No dressing is required.

(iv) The art of brick laying is easy than stone masonry construction.

(v) The bricks can be manufactured at site itself.

(vi) Ornamental work can be easily done with bricks.

(vii) Light partitions, filler walls can be easily constructed by the brick.

General Principles to be Observed in Brick Masonry Construction – General principles to be observed in brick masonry construction as given below –

(i) A good brick masonry should utilise bricks which are sound hard, well burnt and tough with uniform colour, shape and size.

(ii) The bricks should be compact, homogeneous, free from holes, cracks, flaws, air-bubbles and stone lumps. These bricks should be propertly soaked in water for at least two hours before use.

(iii) In the brick work, the bricks should be laid on their beds with the frogs pointing upwards.

(iv) The brick courses should be laid truly horizontal and should have truly vertical joints.

(v) As far as possible the use of brick-bats should be discouraged.

(vi) As far as possible the brick walls should be raised uniformly with proper bond. Generally, the height of brick masonry construction in a day should be less than 1.5 m. The maximum difference in rise of the walls between the different portions should not be more than one metre.

(vii) When the mortar is green, the face joints should be raked to a depth of 12 to 19 mm in order to have a proper key for plastering or pointing. The mortar joints should be stuck flush and finished if no plastering or pointing is to be done.

(viii) In order to ensure continuous bond between the old and the new, the walls should be stopped with a toothed end.

(ix) Finished brickwork in lime mortar should be cured for a period of 2 to 3 weeks. This period can be reduced to 1 to 2 weeks in case of brickwork with cement mortar.

(x) In order to carry out the brick work at higher level, a single scaffolding is used.

Q.90. What do you understand by brick bonds ? What are the different types of bonds used in brick masonry ? ***(R.G.P.V., June 2007)***

Or

Sketch the following bonds in elevation for a brick wall –
(i) English bond (ii) Flemish bond.
Make proper use of king/queen closures. ***(R.G.P.V., Jan./Feb. 2007)***

Or

Describe various bonds used in brick masonry walls.
(R.G.P.V., Nov./Dec. 2007, Dec. 2008, June 2010)

Ans. Bonding is the process of arranging bricks with mortar to tie them together. The vertical joints provides in the brick masonry should not continue. Without proper bonding in between bricks, it is not possible to construct the wall.

There are various types of bonds, generally used in the brickwork as –

(i) Stretcher bond
(ii) Header bond
(iii) English bond
(iv) Flemish bond.

(i) Stretcher Bond – In this type of bond, all the bricks are arranged in the stretcher courses. So wall having stretchers are in the facing.

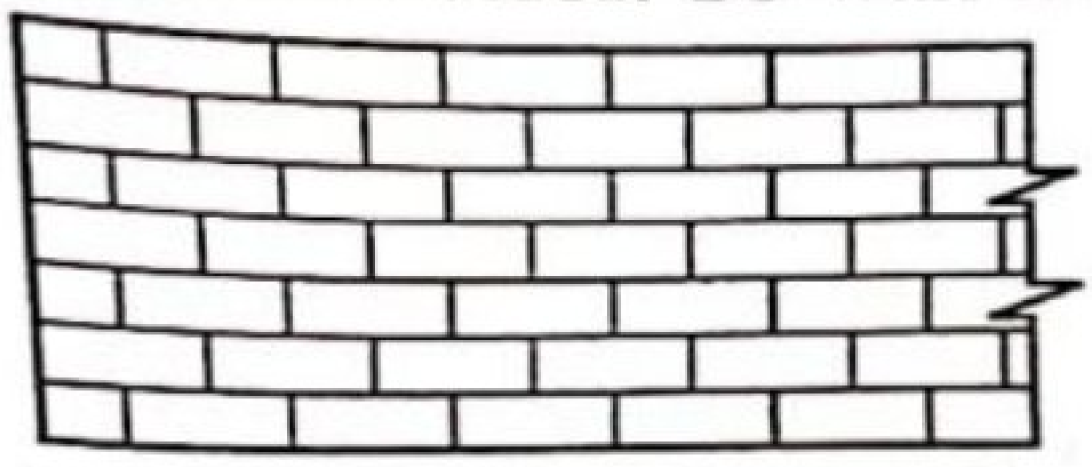


Fig. 1.36 Stretcher Bond

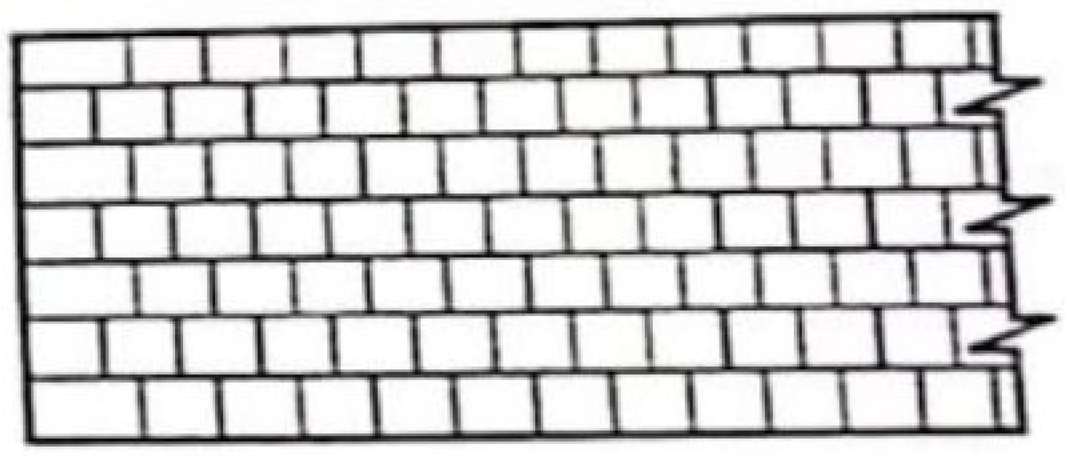


Fig. 1.37 Header Bond

(ii) Header Bond – In this type of bond, all the bricks are arranged in the header courses. So wall having headers in the facing.

(iii) English Bond – In this type of bond there are alternate courses of stretcher and header. A queen closer is placed Just after header to provide the good overlap. The queen closer is not required in the stretcher course.

Fig. 1.38 shows the plans of alternate courses and elevation, with thickness of wall as one brick.

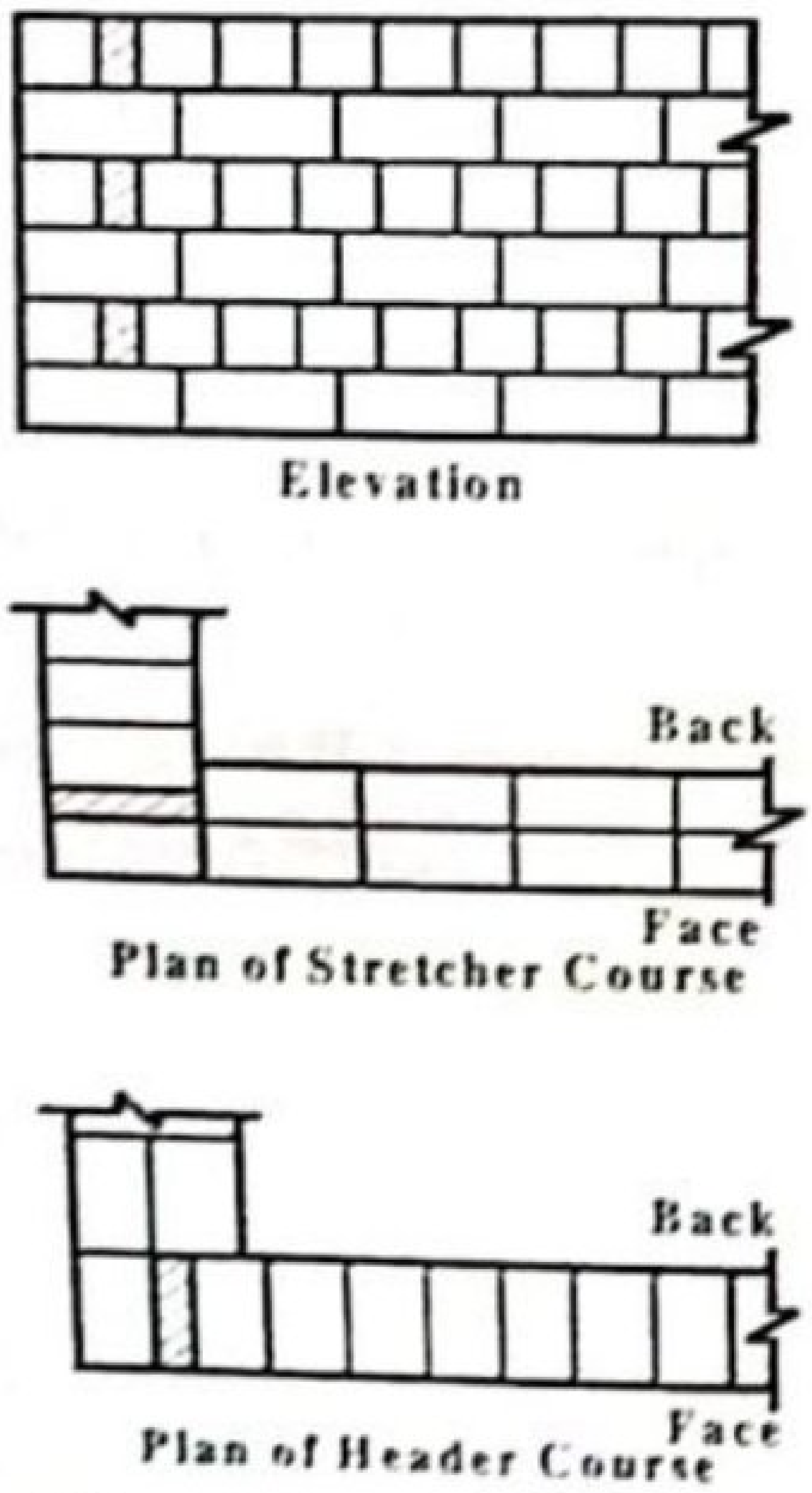


Fig. 1.38 English Bond-1 Brick Wall

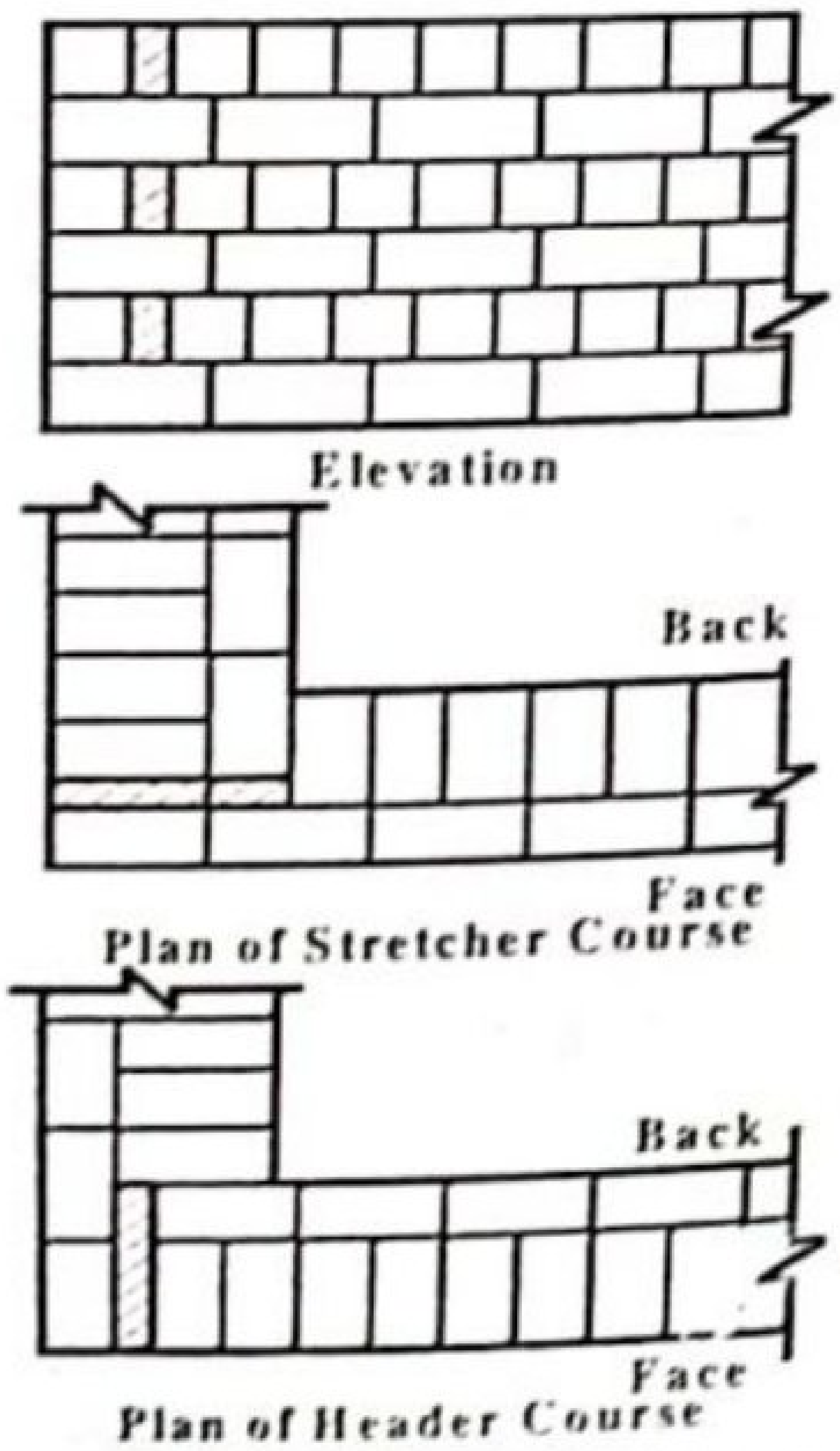


Fig. 1.39 English Bond - 1½ Bricks Wall

This type of bond is generally used in practice. It is considered as the strongest bond in brickwork. Following are the features of an English bond –

(a) The alternate courses consist of stretchers and headers.

(b) The queen closer is put next to the queen header to develop the face lap.

(c) Each alternate header is centrally supported over a stretcher.

(d) If the wall thickness is an even multiple of half-brick, the same course shows headers or stretchers in both the front and the back elevations. But if the wall thickness is an uneven multiple of half-brick, a course showing stretcher on the face shows header on the back and vice versa.

(e) The bricks in the same course do not break joints with each other. The joints are straight.

(f) In this bond, the continuous vertical joints are not formed except at certain stopped ends.

(g) The number of mortar joints in the header course is nearly double than that in the stretcher course. Hence care should be taken to make the header joints thinner; otherwise the face lap disappears quickly.

(h) A header course should never start with a queen closer as it is liable to get displaced in this position.

(i) The queen closers are not required in the stretcher courses.

(j) In the stretcher course, the stretchers have a minimum lap of one-fourth of their length over the headers.

(k) For walls having thickness of two bricks or more, the bricks are laid as stretchers or headers only on the face courses of the wall. The interior filling is done entirely with the headers.

Fig. 1.38 shows the details of one brick wall in the English bond. Fig. 1.38 shows the plans of alternate courses and elevation of brick walls meeting at the corner with thickness of each wall as one brick.

Fig. 1.39 shows the plans of alternate courses and elevation of brick walls meeting at the corner with thickness of each wall as 1½ bricks.

(iv) Flemish Bond – In this type of bond, the headers are distributed evenly and hence, it creates a better appearance than the English bond.

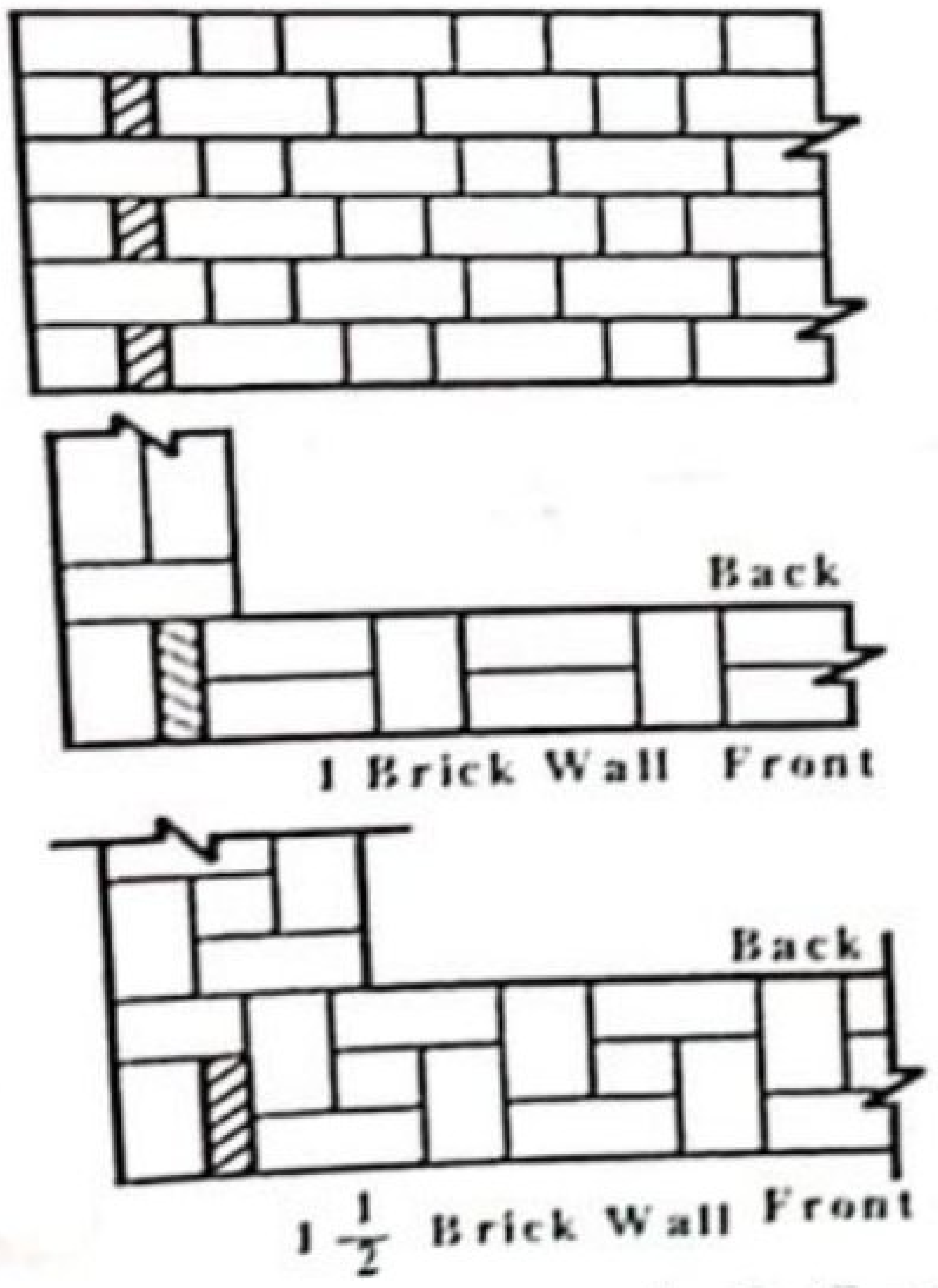


Fig. 1.40 Courses 1, 3, 5 etc. of Double Flemish Bond

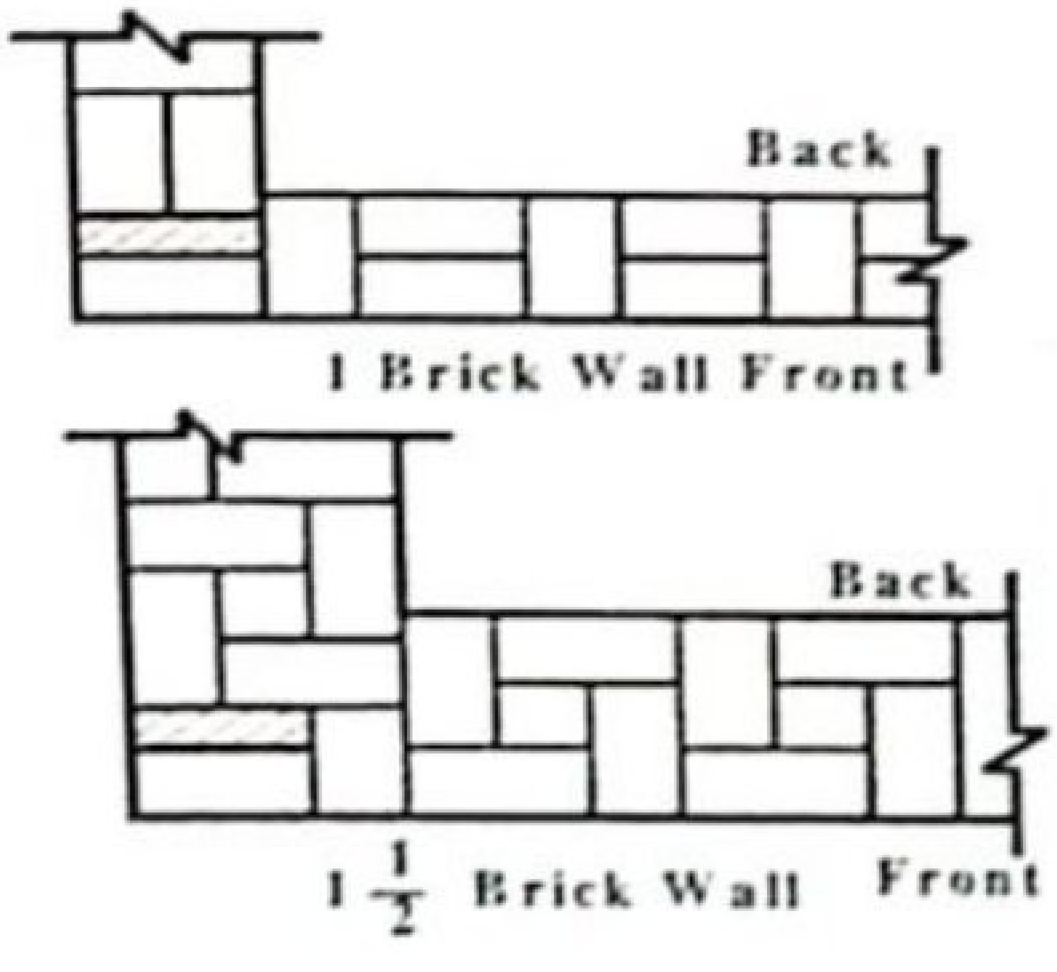


Fig. 1.41 Courses 2, 4, 6 etc. of Double Flemish Bond

Following are the features of a Flemish bond –

(a) In every course, the headers and stretchers are placed alternatively.

(b) The queen closer is put next to the queen header in alternate courses to develop the face lap.

(c) Every header is centrally supported over a stretcher below it.

(d) The Flemish bond may be divided into two groups –

(1) Double Flemish bond,

(2) Single Flemish bond.

In double Flemish bond, the headers and stretchers are placed alternatively in front as well as the back elevations.

For this type of bond, the half bats and three-quarter bats will have to be used for walls having thickness equal to odd number of half bricks. For walls of thickness equal to even number of half bricks, no bats will be required and a stretcher or a header will come out as a stretcher or a header in the same course in front as well as back elevations. This bond gives better appearance than the English bond. But it is not so strong as the English bond as it contains more number of stretchers.

In single Flemish bond, the face elevation is of Flemish bond and the filling as well as backing are of the English bond. Thus, in this type of bond, an attempt is made to combine the strength of the English bond with the appearance of the Flemish bond. This type of bond is used when expensive bricks are used for the face work. But in order to construct this bond, a wall of minimum thickness 1½ bricks is required.

(e) The bricks in the same course do not break joints with each other. The joints are straight.

(f) In this bond, the short continuous vertical joints are formed.

(g) The brickbats are to be used for walls having a thickness equal to uneven number of half-brick.

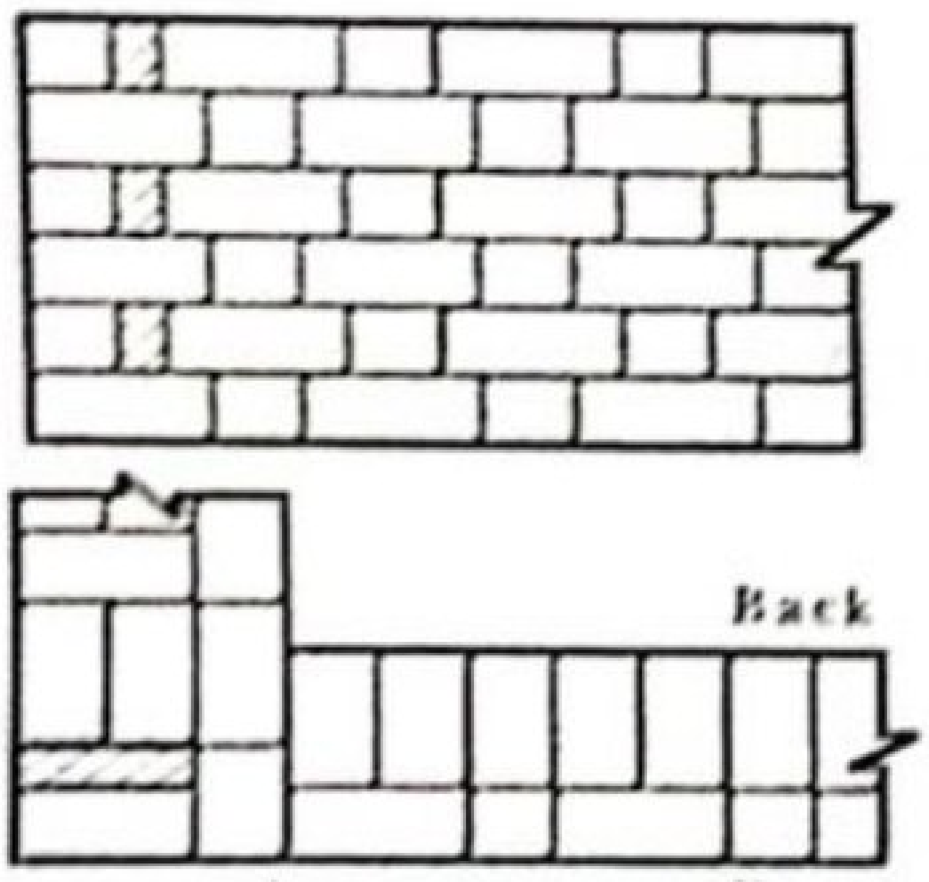


Fig. 1.42 Courses 1, 3, 5 of Single Flemish Bond

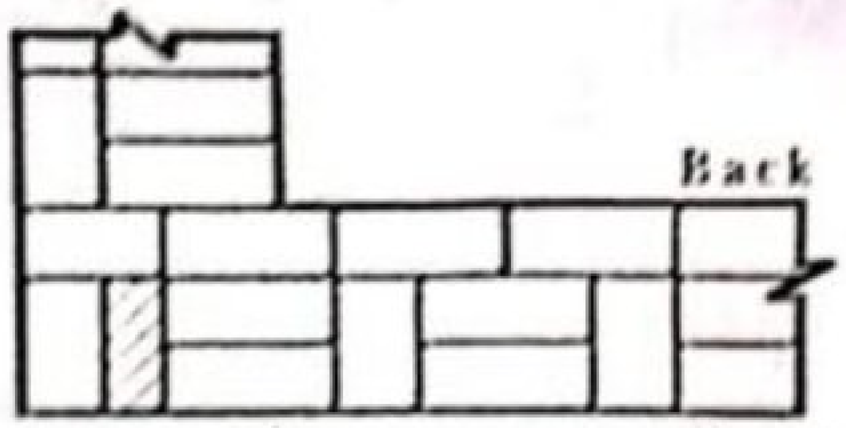


Fig. 1.43 Courses 2, 4, 6 of Single Flemish Bond

Q.91. Differentiate between English bond and Flemish bond.
(R.G.P.V., June 2003, Feb. 2010)

Ans. Differences between English and Flemish bond are given below –

S.No.	***English Bond***	***Flemish Bond***
(i)	For walls of thickness one and half bricks or more the strength is more for this bond.	For walls of one brick thickness this type of bond gives greater strength.
(ii)	Appearance on the facing is not pleasing.	Appearance on the facing is pleasing.
(iii)	This does not require skilled labour.	Skilled labour is required
(iv)	More costly	Less costly due to using brick bats.
(v)	It requires less mortar.	It requires more mortar.

Q.92. Define plastering and pointing. ***(R.G.P.V., June 2016)***

Or

Write short notes on –

(i) Plastering (ii) Pointing. ***(R.G.P.V., Dec. 2016)***

Ans. (i) Plastering – All the external and internal surfaces of masonry, particularly brick masonry work are finished smooth with the help of plaster.

Plastering is the process of covering rough walls and uneven surfaces in the construction of houses and other structures with a plastic material, called plaster or mortar. It protects the masonry work from –

(i) Atmospheric action (ii) Penetration of rain water into wall.

Plastering decorates the wall surfaces and does not allow dust accumulation.

Objects – The principal objectives of plastering the surfaces are as follows–

(i) To provide an even, smooth, regular, clean and durable finished surface and, sometimes, to improve appearance also.

(ii) To preserve and protect the surfaces from atmospheric influences by acting as a protective coating.

(iii) To conceal the defective workmanship.

(iv) To cover up the use of inferior quality and porous materials and the joints formed in masonry work.

(v) To provide a satisfactory base or ground for decorating the surface by applying white washing, colour washing, painting or distempering.

(vi) In case of internal plastering, the basic object is to protect the surfaces against dust and vermin nuisance.

(ii) Pointing – Pointing is the art of finishing the mortar joints in exposed brick or stone masonry with suitable cement or lime mortar, in order to protect the joints from weather effects and also to improve the appearance of building structure. It should be noted that mortar joints are only the weak spots in a structure (structure being made of superior materials) and hence they should be properly protected from the disintegrating effects of rain water, sunrays and snowfall. Pointing, being cheap, can be adopted in places of low rainfall.

Q.93. Explain the method of plastering on wall. Also write the advantages of plastering. ***(R.G.P.V., Dec. 2014)***

Ans. **Methods of Plastering** – The plaster may be applied either in one, two or three coats. Cement plaster is usually appljes in a single coat. But in certain cases when thickness of plaster is more than 15 mm or it is desired to have fines finish, plaster is applied in two coats. The usual proportion is 1 cement and 3 sand. Following is the procedure for carrying out the plaster in cement mortar – (i) The background is prepared. The joints are racked out to a depth of 20 mm. The surface is cleaned, washed with cleaned water and kept wet for 6 hours before plastering. (ii) If the surface is uneven a preliminary coat is applies to make it even.

Advantages – Advantages of plastering are as follows –

(i) It is cheap and economical.

(ii) It is hard and durable.

(iii) It is possible to apply it during all wheather conditions.

(iv) It effectively check the entry or penetration of moisture from the surface.

(v) It possess good workability.

Q.94. Differentiate between plastering and pointing.
(R.G.P.V., June 2007, Feb. 2010, March/April 2010, June 2013)

Ans. Differences between plastering and pointing are given below –

S.No.	*Plastering*	*Pointing*
(i)	It provides an even, regular and smooth surface.	It does not provide even, regular and smooth surface.
(ii)	It conceals the defective workmanship.	It cannot conceal the defective workmanship.
(iii)	It covers the complete surface of the masonry.	It covers only the joints of the masonry.
(iv)	It protects the complete surface of masonry from weather effect.	It protects only the joints of masonry from weather effects.

(v)	It provides a satisfactory base or ground for decorating the surface by applying white washing etc.	It does not provide a satisfactory base or ground for decorating the surface by applying white washing etc.
(vi)	Type of plasters used are lime plaster, cement plaster, mud plaster, water-proof plaster and plaster of Paris.	Type of pointings used are beaded pointing, weather pointing, flush pointing and 'V' pointing.

FLOORS, ROOFS

Q.95. What do you mean by floors ?

Ans. Floors are solid constructions which divide a building into different level surfaces capable of supporting the occupants of a building, furniture, equipments etc. The floors are classified as ground floor and upper floors.

The floor resting directly on ground surface is known as ground floor while other floors of each storey, situated above the ground level are termed as upper floors.

Q.96. Give a list of materials which are commonly used as floorings and give a brief description of each material. ***(R.G.P.V., Dec. 2013)***

Ans. The type of flooring depends upon the selection of materials. The materials for flooring are selected considering the factors as the initial cost of building, type of building, appearance, cleanliness, durability damp resistance, sound insulation, thermal insulation, fire resistance etc.

Following are the type of floorings –

(i) Mud flooring or mooram flooring
(ii) Flag stone flooring
(iii) Brick flooring
(iv) Cement concrete flooring
(v) Terrazzo flooring
(vi) Mosaic flooring
(vii) Tiled flooring
(viii) Marble flooring
(ix) Timber flooring
(x) Rubber and cork flooring
(xi) Plastic or P.V.C. flooring.

(i) Mud Flooring – Mud flooring is generally used in villages of India. It is cheap, hard, fairly impervious and easy in construction and maintenance. For mudfloors construction, a 25 mm thick layer of selected, moist earth is spread over the prepared bed and it is then rammed well.

(ii) Flag Stone Flooring – This flooring consists of thin slabs of stones laid on concrete bedding the usual size of stone slabs are 30 cm × 30 cm, 45 cm × 45 cm and 60 cm × 60 cm.

(iii) Brick Flooring – This type of flooring is used in cheap construction. This flooring is suitable for warehouse, stores, godowns, etc. Well burnt bricks of good colour and uniform shapes are used. Bricks are laid either flat or on edge, arranged in any good looking fashion.

(iv) Cement Concrete Flooring – This is commonly used for residential, commercial and even industrial buildings.This type of flooring is cheap, durable and easy in construction. The floor consists of base concrete and wearing surface. The base layer 7.5 to 10 cm thick with lean cement concrete of lime-concrete with 40 per cent mortar of 1: 2 lime-sand and 60 per cent of coarse aggregates. The wearing surface is made up of 1: 2: 4 cement concrete of desired thickness about 4 cms in a single operation in the panel. The panels may be 1 m × 1 m or 2 m × 2 m.

(v) Terrazzo Flooring – This is a special type of concrete flooring in which marble chips are used as aggregates with pozzolana dana and this concrete on polishing with carborundum stone presents a smooth surface. The terrazo flooring is used in banks, hotels, offices, public and social buildings. Any desired colour can be obtained by using marble chips of different colours.

(vi) Mosaic Flooring – Mosaic flooring consists of small pieces of marble or pozzolana dana arranged in different pattern with cement. A concrete subbase is prepared over which 3 to 4 cm cement mortar is spread and levelled. A 5 cm thick cementing material (cement slurry + marble pieces or pozzolana dana) is spread and left to dry for about 24 hours, and then it is rubbed with carborundum stone to set a smooth and polished surface.

(vii) Tiled Flooring – Tiled flooring is constructed from square or other shapes, made up of clay, cement, concrete, or terrazzo. These tiles are available in different sizes and thickness. These are used for residential buildings, offices, schools and other public buildings. The tiles are laid on the bedding mortar. In bedding mortar, lime mortar 1: 3 is used in a 25 cm to 30 cm thickness.

(viii) Marble Flooring – This type of flooring is commonly used for superior type of floor construction like in hospitals, temples, bathroom, theatres etc. The base concrete is prepared in the same manner as that for concrete flooring. Over which cement mortar is laid down. The marble slab is then laid over it. The grinding is done with carborundum stone to get a smooth and polished surface. Finally the floor is polished with the mansion polish to provide smoothness and shining.

(ix) Timber Flooring – Timber flooring is used in dancing halls, or in auditorium. These type of floorings are costly.

Q.97. Distinguish between terrazzo and mosaic flooring.

Ans. Differences between terrazzo and mosaic flooring are given below –

S.No.	Terrazzo Flooring	Mosaic Flooring
(i)	It is the type of flooring in which marble chips are used with pozzolana dana.	It consists of small pieces of marble or pozzolana dana arranged in different pattern with cement.
(ii)	It is used in beramdas, courtyards, galleries etc.	It is used in rooms, kitchen etc.
(iii)	It provide smoother surface than mosaic flooring.	It provide less smoth surface than terrazzo flooring.
(iv)	It can be arranged in different patterns and colours by means of marble chips.	It can be arranged in different patterns and colours by using coloured cement.

Q.98. What do you understand by roof ?

Ans. A roof is the uppermost part of the building which is supported on structural members and covered with a roofing material. Roof protect the building from the damaging effects of weather elements such as rain, wind, heat, snow etc. Life of the building is increased by the roof. Good roof protect the building against deterioration starting from the top. There are various factors those are kept in mind before selecting a roof such as weather, heat insulation, strength and stability, lighting, sound insulation, ventilation, etc.

Q.99. What are various types of roof and where are they used ? Give details of various roofing material commonly used. (R.G.P.V., Jan./Feb. 2006)

Ans. There are different types of roofs as follows –

(i) Pitched or Slopping Roofs – Pitched roofs are those which have the decks or surfaces with considerable slope for covering the building structure either of wood or steel. Generally, pitched or slopping roofs are very suitable to coastal regions where rainfall is heavy but the temperature is more or less equal.

(ii) Flat Roofs – A roof which is nearly flat i.e. agnle to the horizontal less than 10 is known as flat roof. Flat roofs are suitable in plain area.

(iii) Shell or Curved Roofs – Shell roofs are three-dimensional structures consisting of thin membrane slabs, curved in one or more directions which transfer the loads on points of support, i.e. columns, etc. Shell roofs are built of several materials, viz, timber, steel sheets, etc. but R.C.C. shell roofs are most popular in the modern age. Shell or curved roofs are generally used in factories, workshops, assembly halls, theatres, recreation halls, libraries, etc.

(iv) ***Domes*** – Domes are special types of shell roofs, having semi-spherical or semi-elliptical shapes, which are used for covering large circular areas (in plan) of structure such as assembly halls, gymnasiums, field houses and other monumental structures.

There are different roof coverings which are commonly used are as follows –

(i) ***Thatch Covering*** – This form of covering is extensively used in sheds, low-cost houses and village buildings. It is considered suitable for rural areas because it forms the cheapest and the tightest material as a roof covering. Moreover, it is simple to construct and keeps the building cool. Thatch covering made from straw or reed is used.

(ii) ***Shingles*** – The use of wood shingles as a roof covering is generally restricted to hill areas where wood is easily and cheaply available in abundance.

Wood shingles are nothing but the sawn or split thin pieces of wood resembling slates or tiles. To form continuous roof covering, wood shingles are laid in a similar manner as slates and tiles, described later. Shingle strips are driven on rafters and shingles are nailed on their top. Generally, at the eaves, two courses of shingles are laid directly one over the other.

(iii) ***Tiles*** – The use of tiles is one of the oldest methods of roof covering. The tiles are named according to their shape and pattern, and they are manufactured in the similar manner as bricks. The clay tiles are of various types, such as flat tiles, pan tiles, pot tiles or half round country tiles and patent tiles such as Mangalore.

(iv) ***Asbestos Cement Sheets, i.e., A.C. Sheets*** – Asbestos cement is a material which consists of portland cement and asbestos fibres (about 15%). Roof coverings made of this material are cheap, tough, durable, watertight, fire resisting and light in weight. A.C. sheets roof covering is commonly adopted for factories, workshops, offices, garages, cinemas and residential buildings.

(v) ***Galvanized Corrugated Iron Sheets*** – These sheets are extensively used as a roof covering material in factories, workshops, sheds, cheap buildings, etc. Though galvanized corrugated iron sheets do not have an attractive appearance but still they are widely used as they are very durable, fire-proof, light in weight and require no maintenance. These sheets are manufactured in a form which have the corrugations (i.e., a series of parallel depressions) from one end to another. These sheets are laid with corrugations running down the slope of the roof. The purpose of corrugations is to impart additional strength to thin iron sheets and to discharge the water quickly away from the sheets. The iron sheets are galvanized with zinc to protect them from the rusting action of wet weather.

(vi) Slate – A 'Slate' is a sedimentary rock, normally blue grey in colour, capable of being split and dressed into thin sheets for use as roof coverings. Stone slate forms the most durable of all the roof coverings.

A good slate should be hard tough and durable, of rough texture, ring bell like when struck with finger, not split when holed or pressed, non-absorbent, free from white patches and of uniform colour throughout. A good slate should not absorb more than 2% of its weight when soaked in water for 24 hours.

Q.100. Compare between G.I. sheets and A.C. sheets for roof covering.

Ans. **Comparison between G.I. Sheets and A.C. Sheets**

S.No.	*G.I. Sheets*	*A.C. Sheets*
(i)	Not breakable and can be handled with little care.	Breakable and requires much care in handling.
(ii)	Sheets can be made very thin.	Cannot be made as thin as G.I. sheets.
(iii)	High in initial cost.	Cheap in initial cost.
(iv)	Easily corroded by atmospheric actions.	Do not corrode.
(v)	Non-fire-resisting and deformed when a fire occurs	Fire-resisting.
(vi)	Light in weight.	Heavy in weight.
(vii)	Noisy when something falls over them.	Less noisy when something falls over them.
(viii)	Maintenance cost is more due to periodic painting to resist corrosion.	Maintenance cost is practically nil, if not damaged.
(ix)	Appearance is not pleasing even if a neat finish is made.	Neat and pleasing appearance can be achieved.
(x)	Affected by acids and fumes.	Not affected by acids and fumes.
(xi)	Hot in summer and cold in winter	Not much affected by temperature.
(xii)	Less possibility of getting damaged due to external forces.	Possibility of getting damaged due to external forces.
(xiii)	Prepared from wrought-iron plates and then galvanized.	Prepared from a mixture of cement and asbestos fibres sound-proof.
(xiv)	Not sound-proof.	Sound-proof.

Q.101. Explain in brief slopping roofs. How they are classified ?

Ans. Pitched roofs are those which have the decks or surfaces with considerable slope for covering the building structure either of wood or steel. These types of roofs are generally provided in the regions of heavy rain.

These roofs are classified into following heads –

(i) Single roofs (ii) Double or purlin roofs (iii) Trussed roofs.

(i) ***Single Roofs*** – These roofs consist only of common rafters, which are secured at the ridge and wall plates. Single roofs are of various forms as following –

(a) Lean-to-roof (b) Couple roof
(c) Couple close roof (d) Collar-beam roof.

(a) Lean-to-Roof – These are generally covers the verandah of a building and projected from the main wall of the building. In this roof, common rafters are inclined at 30° against a wall as shown in fig. 1.44. These type of roofs are suitable for a maximum span of 2.5 metres.

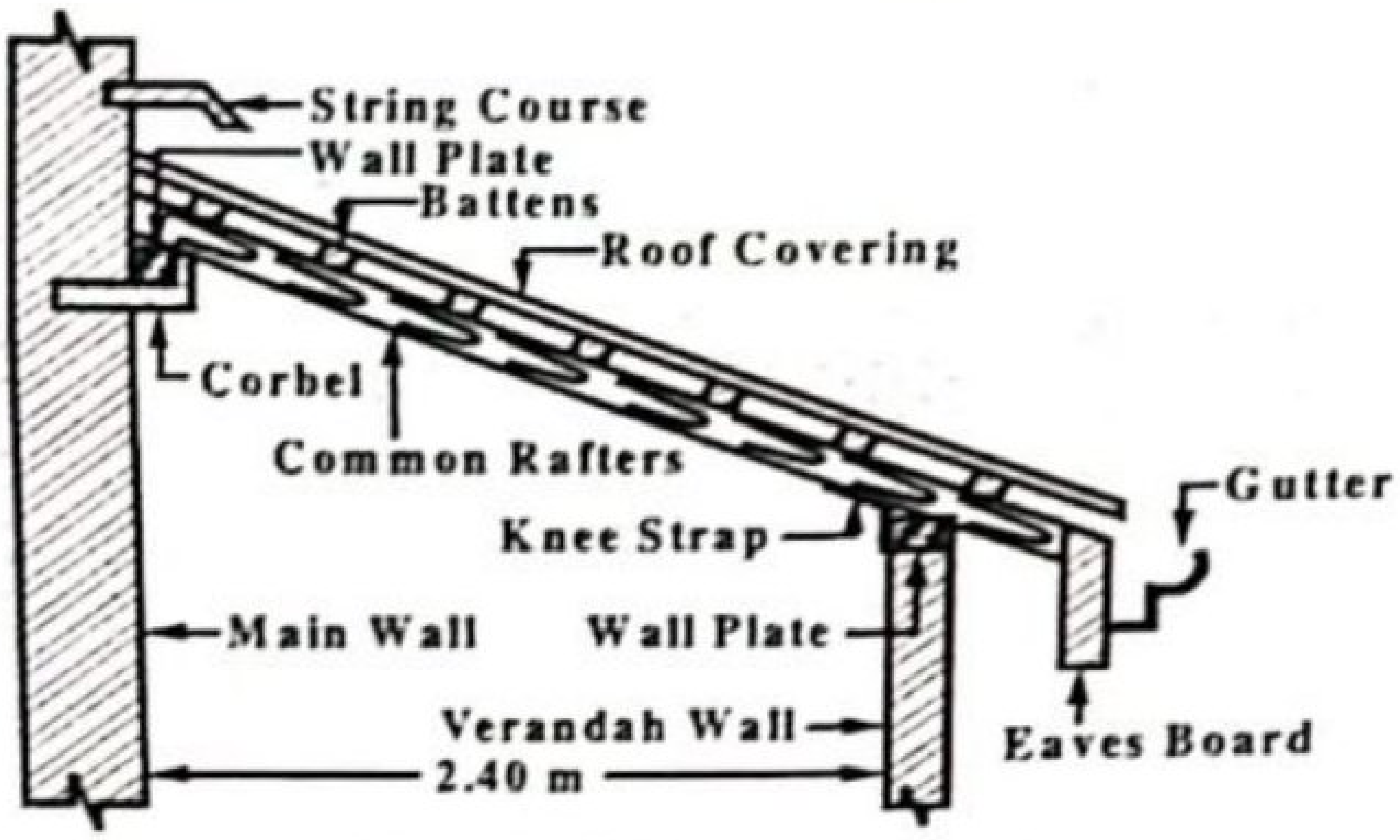


Fig. 1.44 Lean-to-Roof

Upper ends of the common rafters are placed on a wooden wall plate, placed on corbel. The lower ends of these common rafters are nailed to a wooden post-plate which is joined to the top of posts on verandah wall.

(b) Couple Roof – In this type of roof, pair of the common rafters are placed upward from the side walls and they are supported at the upper ends at the ridge piece in the middle as shown in fig. 1.45. These roofs are generally adopted for a maximum span of 3.5 metres. These type of roofs are not generally used because it has a tendency to spread at the feet and thrust out the walls.

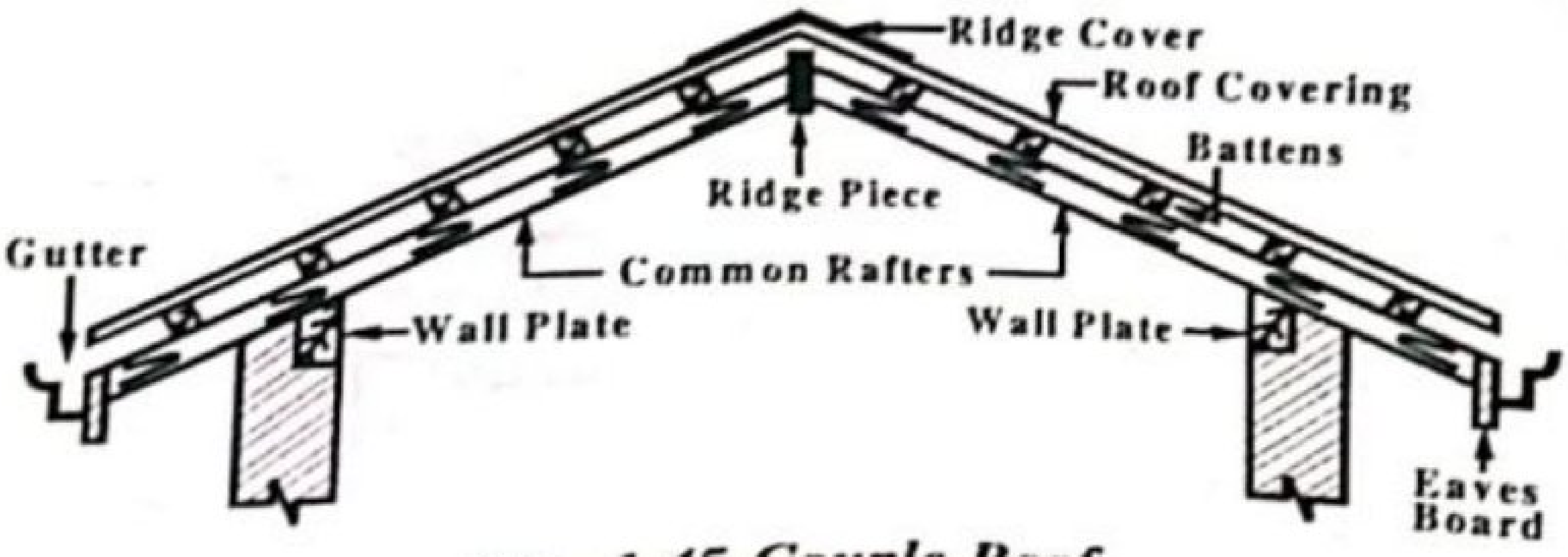


Fig. 1.45 Couple Roof

(c) Couple-Close-Roof – This type of roof is similar to a couple roof, only difference is that the common rafters are closed by a horizontal tie known as tie-beam. This tie may be of wool or steel. This type of roofs can be used for a maximum span of 4.5 metres. Fig. 1.46 shows this type of roof.

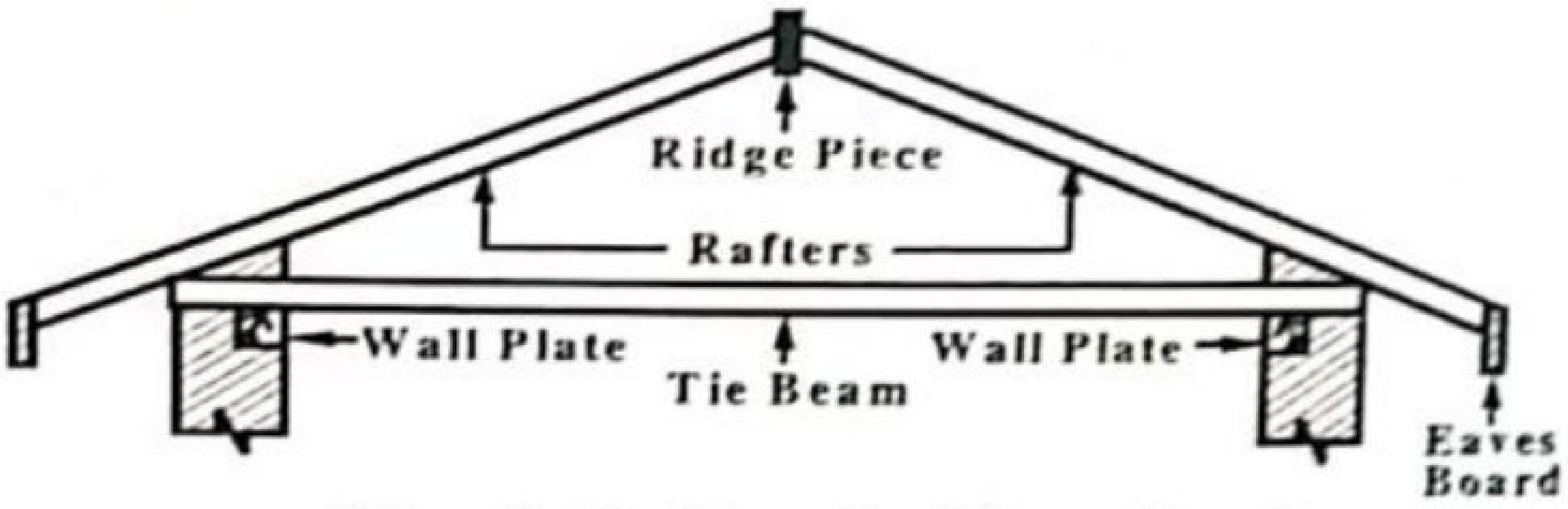


Fig. 1.46 Couple-Close Roof

(d) Collar-Beam Roof – This type of roof is similar to the couple close roof only difference is that, the horizontal tie is now raised up from the feet of the rafters to almost middle of rafters as shown in fig. 1.47. That raised up tie is known as collar beam. These roofs are suitable for spans of 4.0 to 5.5 metres.

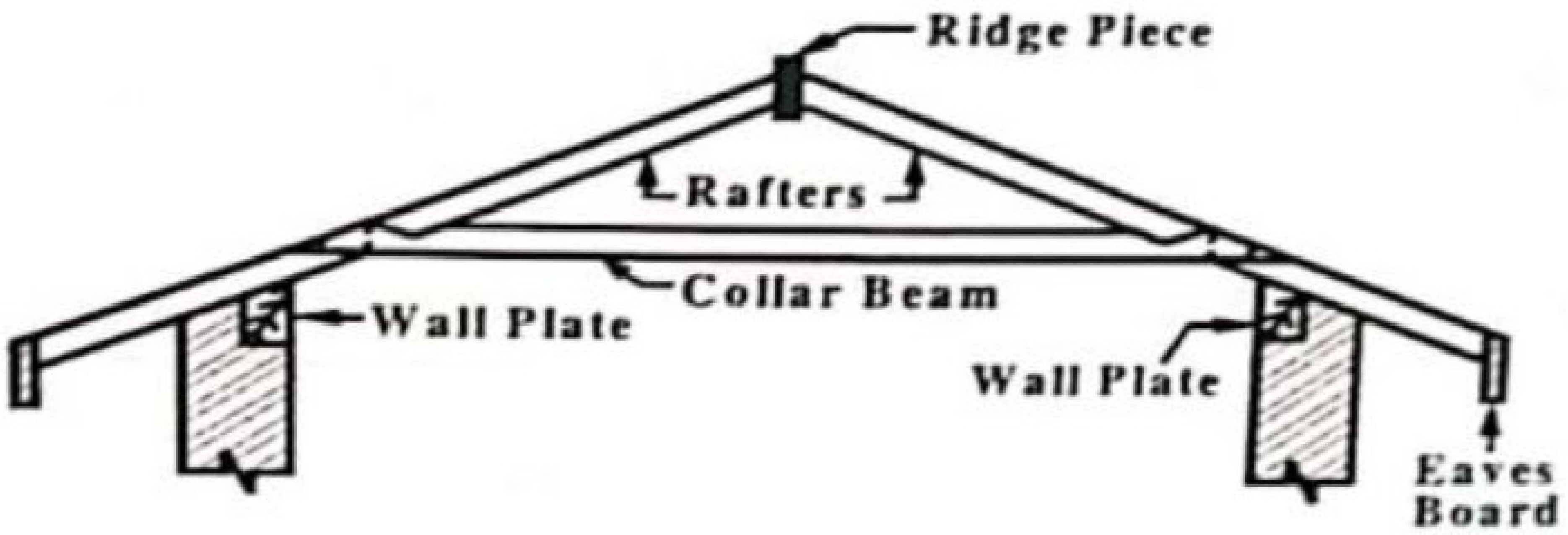


Fig. 1.47 Collar-Beam Roof

(ii) Double or Purlins Roofs – In this type of roof, a purlins is attached to support the common rafters at the intermediate points, as shown in fig. 1.48. These roofs are suitable for 5.5 metres span. The function of purlins is to support the rafters together and acts as intermediate supports.

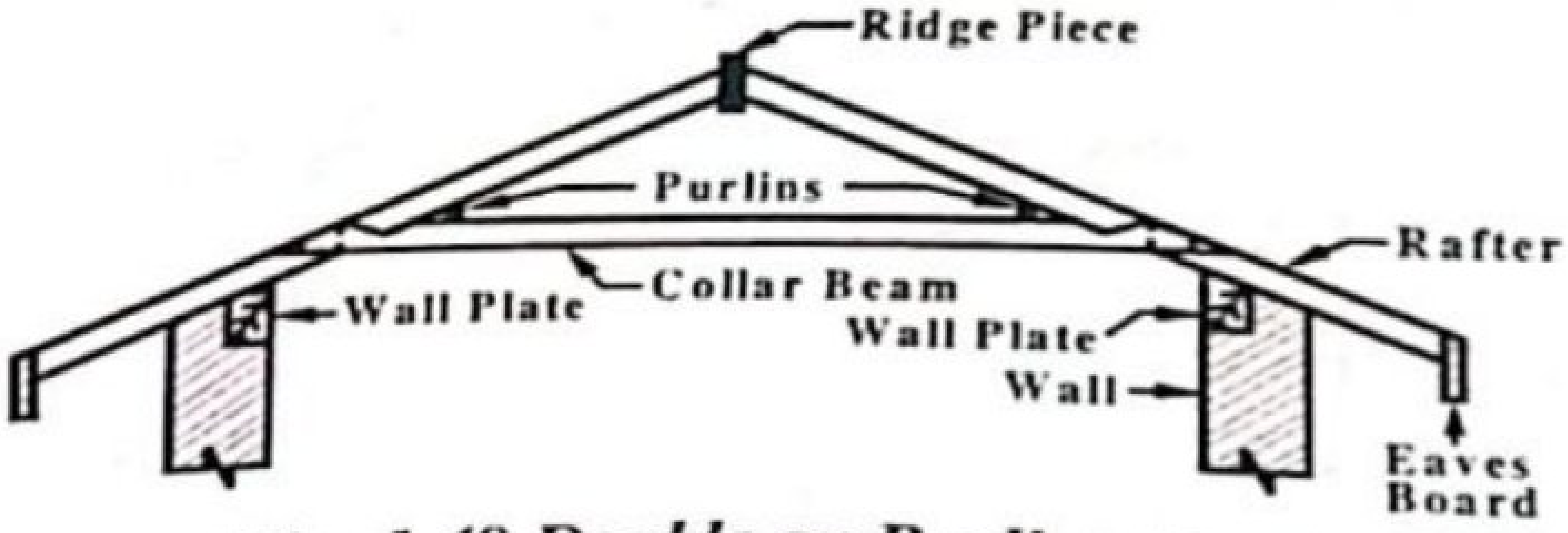


Fig. 1.48 Double or Purlins Roofs

(iii) Framed or Trussed Roofs – Truss roof is the combination of three sets of members, i.e., common rafters, purlins and truss. These are generally adopted for long spans. In roof truss, load of the roof covering material transfer to rafters, which distribute this load to purlins, which transfer this load to the trusses and finally all load is transfer to the walls. These are generally used for the spans more than 5 metres. The usual forms of roof trusses are as follows –

(a) King-post truss	(b) Queen-post truss
(c) Mansard roof truss	(d) Bow-string truss
(e) Composite roof truss	(f) Steel slopping roof truss.

(a) King Post Truss – This is the wooden truss. It is suitable for spans varying from 5 to 9 metres. It consists of two principal rafters, a tie beam, a king post and two struts as shown in fig. 1.49.

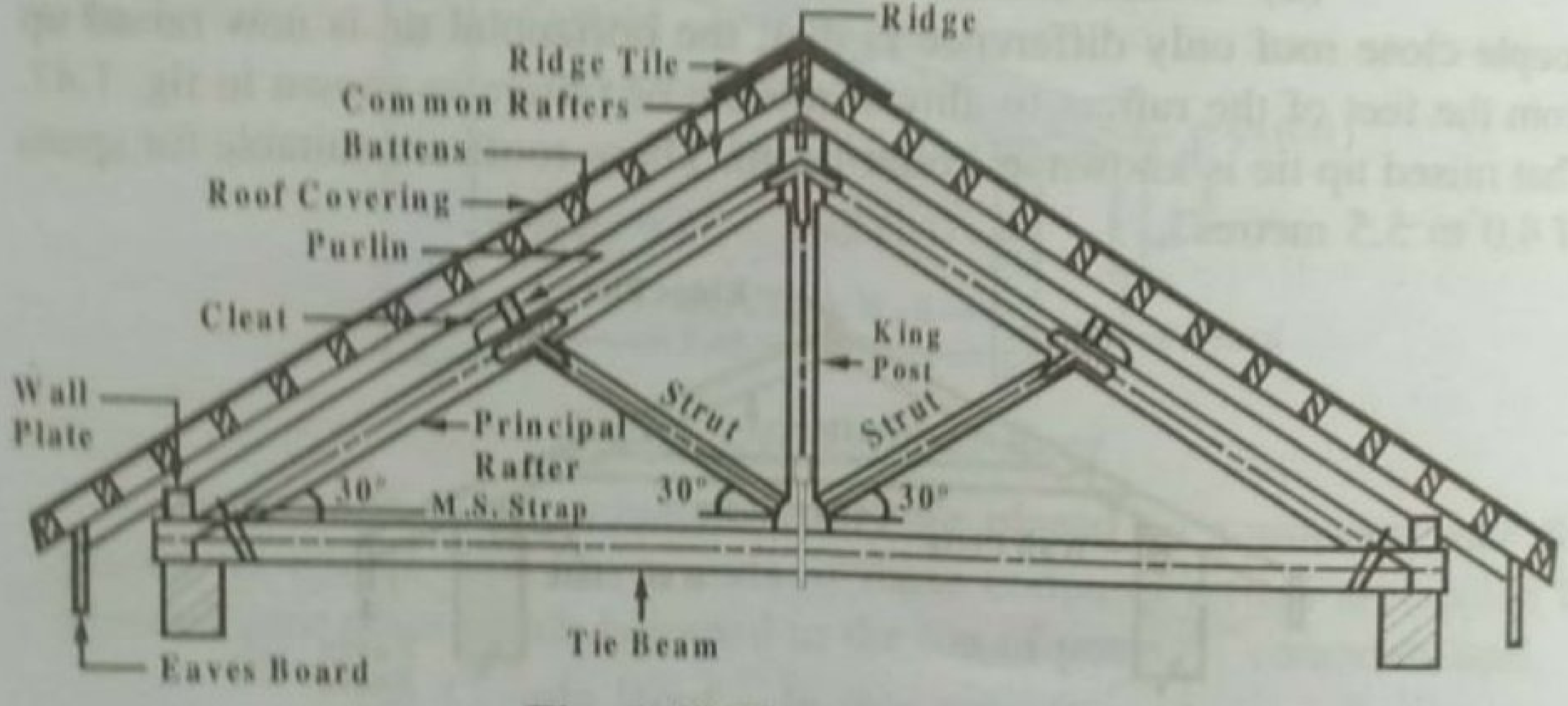


Fig. 1.49 King Post Truss

The central upright portion is called king post. It prevents the tie beam from sagging at its centre. It is made up of various elements. Purlins are placed over the joints of principal rafters and they support the common rafters. Cleats are the pieces which fixed on principal rafter to prevent the purlins from tilting. The common rafters rest on the purlins. The battens or reepers are nailed across the common rafter. The roof covering is then laid over it.

(b) Queen Post Roof Truss – Its having two wooden uprights or vertical members, known as queen-posts, instead of a king-post, as shown in fig. 1.50. The truss consists of two queen-posts, two principal rafters, struts, tie-beams, straining sill, purlins, cleats, etc.

The queen posts prevent the sagging in the tie beam. The upper ends of the queen-posts is kept in position by straining beam. The straining sill, is fixed on the tie beam, between the feet of queen posts.

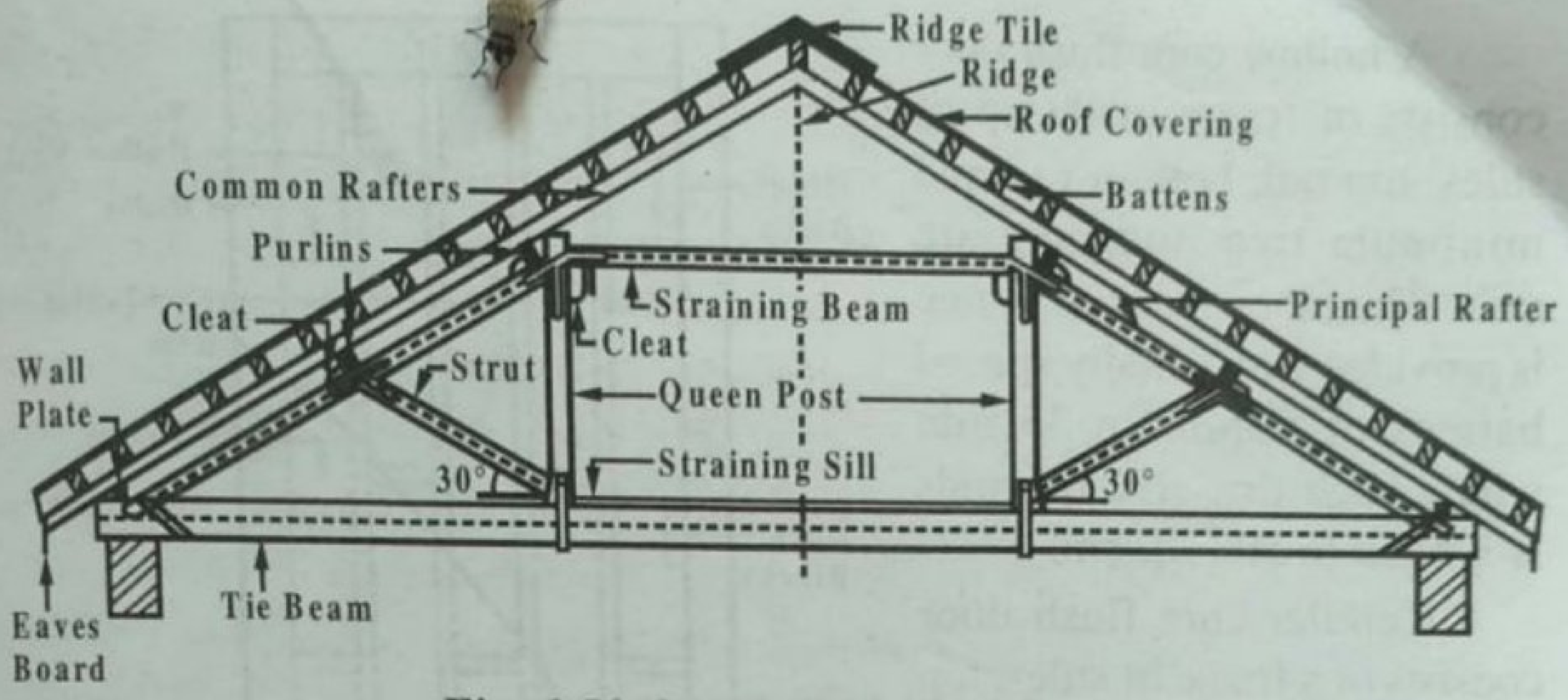


Fig. 1.50 Queen Post Roof Truss

DOORS, WINDOWS, LINTELS

Q.102. What do you mean by doors ?

Ans. A door may be defined as a barrier which can be opened and secured in wall opening. Door is provided to give an access to the inside of a room of a building. It serves as a connecting link between the various internal units of a building.

Door consists of two parts door frame and door shutter. The door shutter is held in position by door frame which is fixed in wall opening.

Q.103. Describe the types of the doors. (R.G.P.V., June/July 2006)

Ans. The different types of doors are as follows –

(i) ***Flush Doors*** – Flush doors are popular now-a-days because of their pleasing appearance, simplicity of construction, better strength, less cost and greater durability. These are used for both residential, public and commercial buildings.

Flush doors are of two types as –

(a) Solid core or laminated core

(b) Hollow core and cellular core.

Ans also diagram

Fig. 1.51 shows, solid core or laminated core flush door consists of the wooden frame consisting of stiles, top and bottom rails is used for holding the core. The core consists either of core-strips of timber glued together under great pressure and faced on each side by plywood sheets, or of block board or particle board, faced with plywood sheets. In each type of core, plywood sheets are glued together under pressure to the assembly of core housed in the frame on both the faces.

A hollow core flush door consists of frame made up of stiles, top rail, bottom rail and minimum two intermediate rails. The inner space of frame is provided with equally spaced battens of minimum 25 mm width, such that area of voids is limited to 500 sq. cm.

Cellular core flush door consists of a frame of stiles, top rail and bottom rail, each of a minimum 75 mm width, with the void space filled with equidistant battens of wood of plywood each of 25 mm width. The battens are so arranged that the void space does not exceed 25 sq. cm in area. The total area of voids does not exceed 40 percent of the area of shutter.

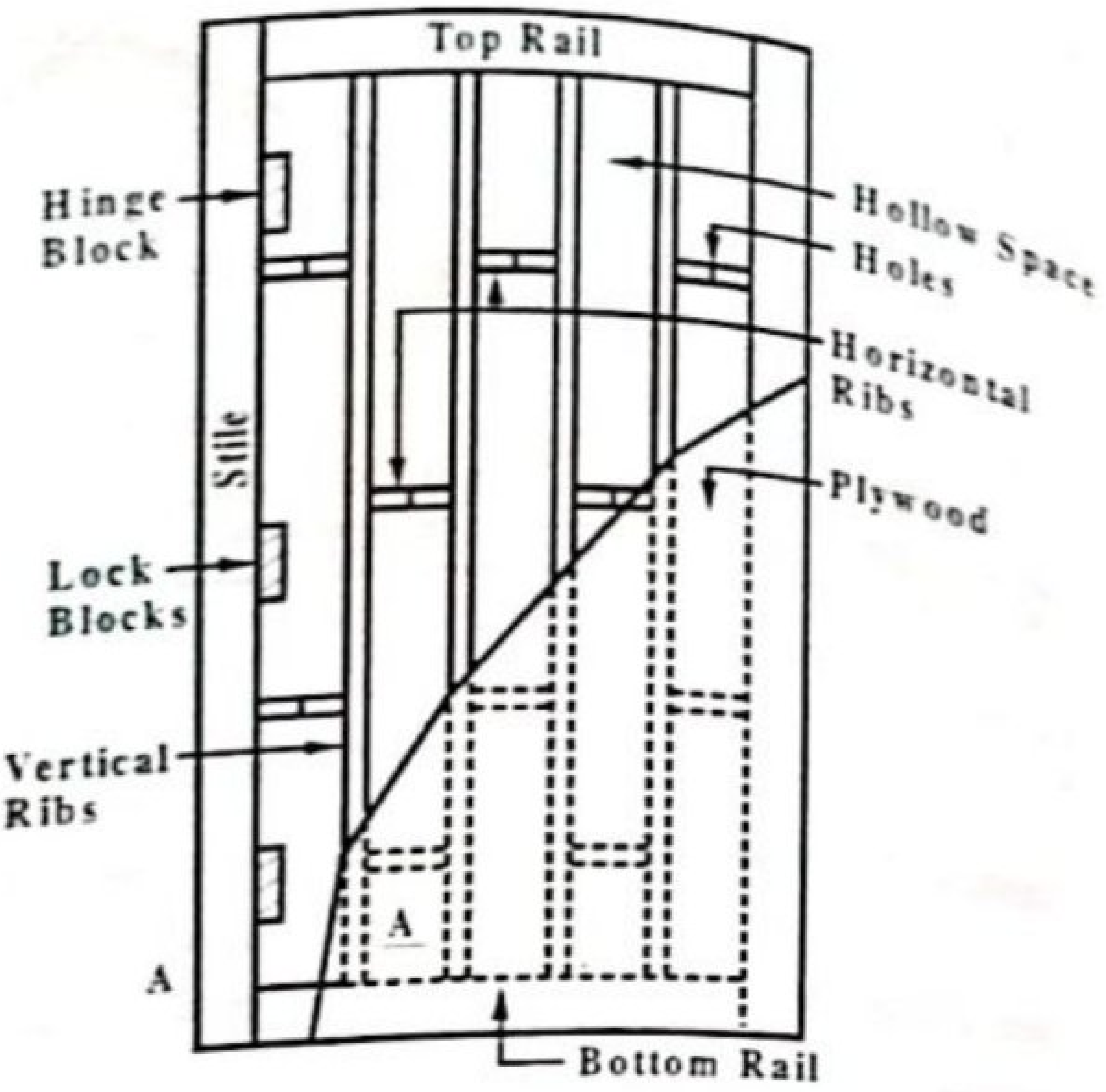


Fig. 1.51 Flush Door

(ii) Collapsible Steel Doors – These doors neither require hinges for opening and closing the shutters nor any frame for hanging them. These doors are extensively used for main entrance of residential buildings, shops, garages, public buildings, sheds, godowns, etc., where the width of the door is large and the space is insufficient to provide two leafed hinged shutters. These doors being very strong, can be used in exposed situations to safeguard against burglars. These doors may be made of single or double shutters depending upon the size of the opening. A double shutter collapsible door has been illustrated in fig. 1.52.

These doors are fabricated from vertical pieces of rolled steel channels, 16 mm to 20 mm wide, joined together with the hollows of the channels on the inside, leaving a vertical gap between them of 12 to 20 mm. Rollers are provided

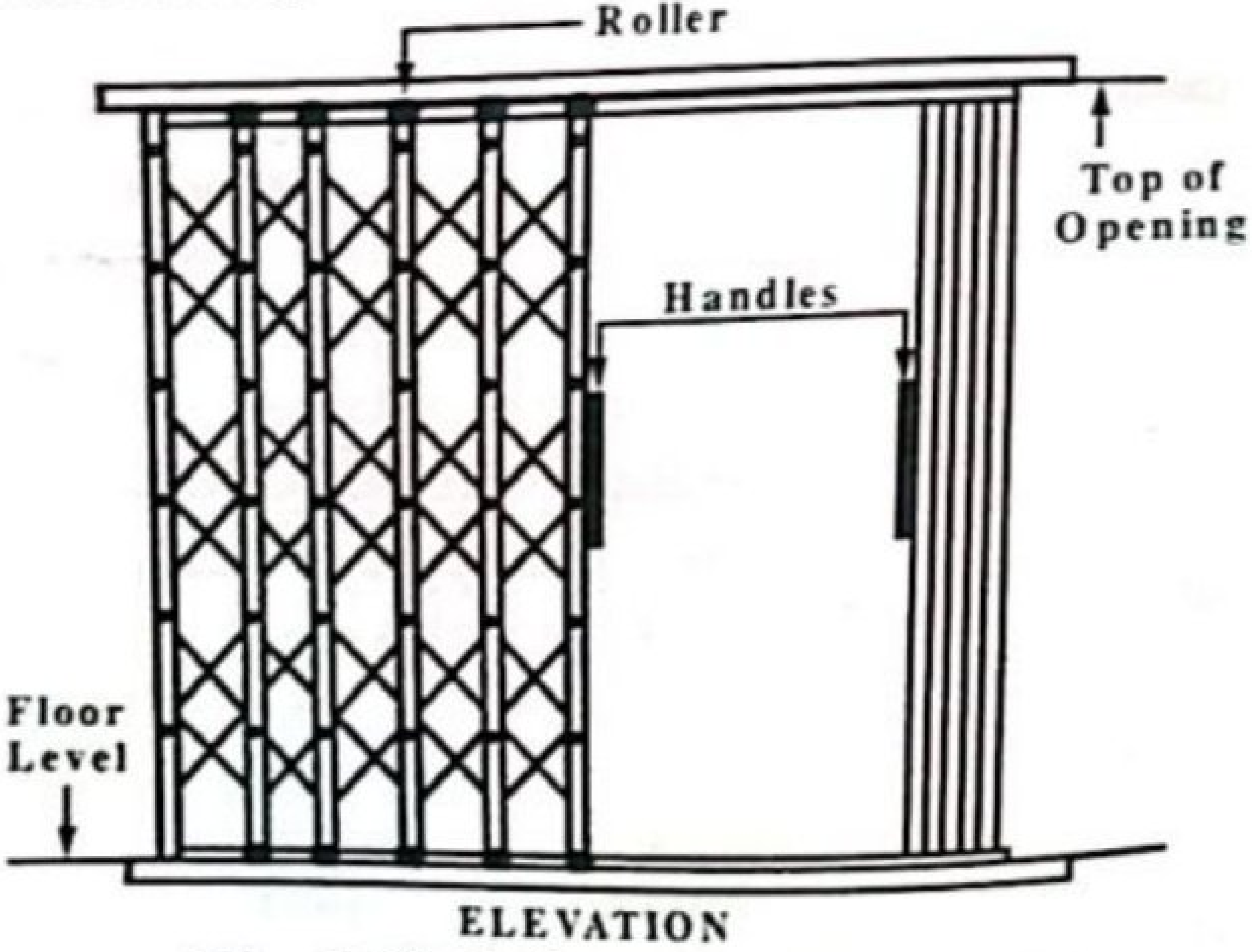


Fig. 1.52 Collapsible Steel Door

both at their top and bottom or at the top only in special cases. The doors can be opened or closed by a slight pull or push. The vertical channel pieces are spaced at 10 to 12 cm centre to centre and are joined to one another by means of hoop iron cross pieces or flats 16 mm to 20 mm wide and 5 mm thick which allow the door to open or fold.

(iii) Revolving Doors – Revolving doors provide entrance on one side and exit on the other side simultaneously. These doors keep the opening automatically closed when it is not in use. These doors are provided where there is a constant foot traffic of people entering and going out of an entrance in public buildings, such as banks, hotels, offices, hospitals, theatres, etc. These doors are also used in hill stations to avoid strong wind blowing in. These doors are also considered very suitable for the entrance of airconditioned buildings, as they offer the advantage of keeping the interchange of inside and outside air to the minimum, or in other words they exclude the draught of cold or hot air through them.

A revolving door consists of four upright cross wings, i.e., shutters, which are arranged diagonally on the sides of a centrally placed pivot. These cross-wings or shutters revolve about this pivot or vertical axis, as shown in fig. 1.53.

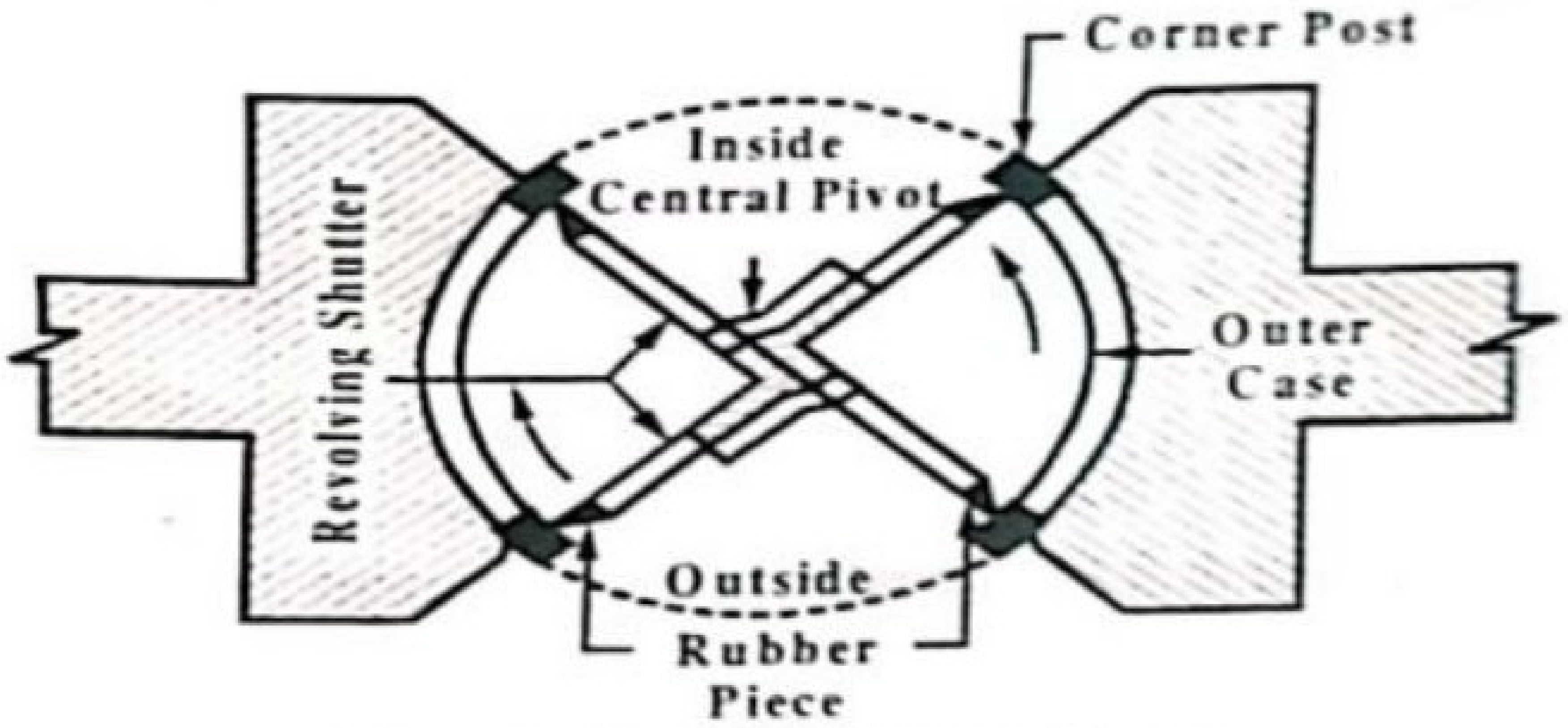


Fig. 1.53 Revolving Door

(iv) Swinging Doors – Swinging doors, which may either be single acting type or double acting type, are used in passages of public buildings, like offices, banks, etc. and also in kitchens, pantries, dining rooms, etc.

In addition to the doors swinging action in one or both the directions, they may have one leaf or shutter hinged on one edge or may have two leaves (or shutters) hinged on the opposite edges and meeting at the centre. The shutters are fixed with special hinges known as double action spring hinges which hold the shutter in closed position when not in use. The details of a single shutter double-acting swinging door are given in fig. 1.54.

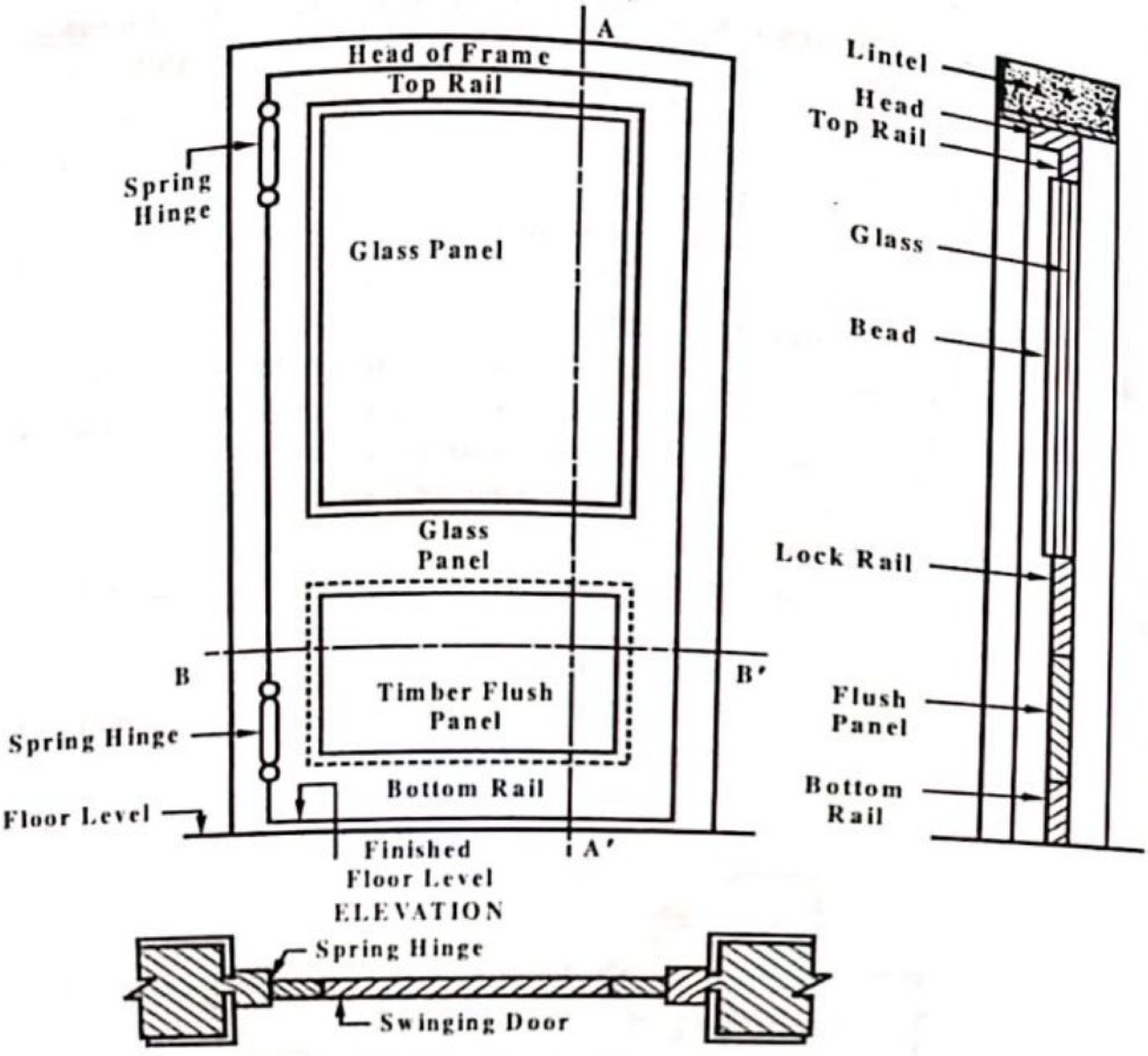


Fig. 1.54 Details of a Swinging Door

(v) Rolling Steel Doors – These doors are capable of being rolled up at the top easily and cause no obstruction either in the opening or in the floor space. These are commonly used these days for the main entrance of shops, garages, godowns, show windows, show-room openings and doors, etc. These doors are sufficiently strong and offer proper safety to glass and the interior when closed. They also provide safety against fire and burglars.

A rolling steel door consists of a frame, a drum and a shutter of thin steel plates or iron sheets of thickness about 1 mm and width varying upto 6 metres. Steel guides are provided on the sides for the movement of shutters. The door is counter-balanced by means of helical springs enclosed in the drum, and a hood of steel protects the drum from the weather. The details of such a door are shown in fig. 1.55.

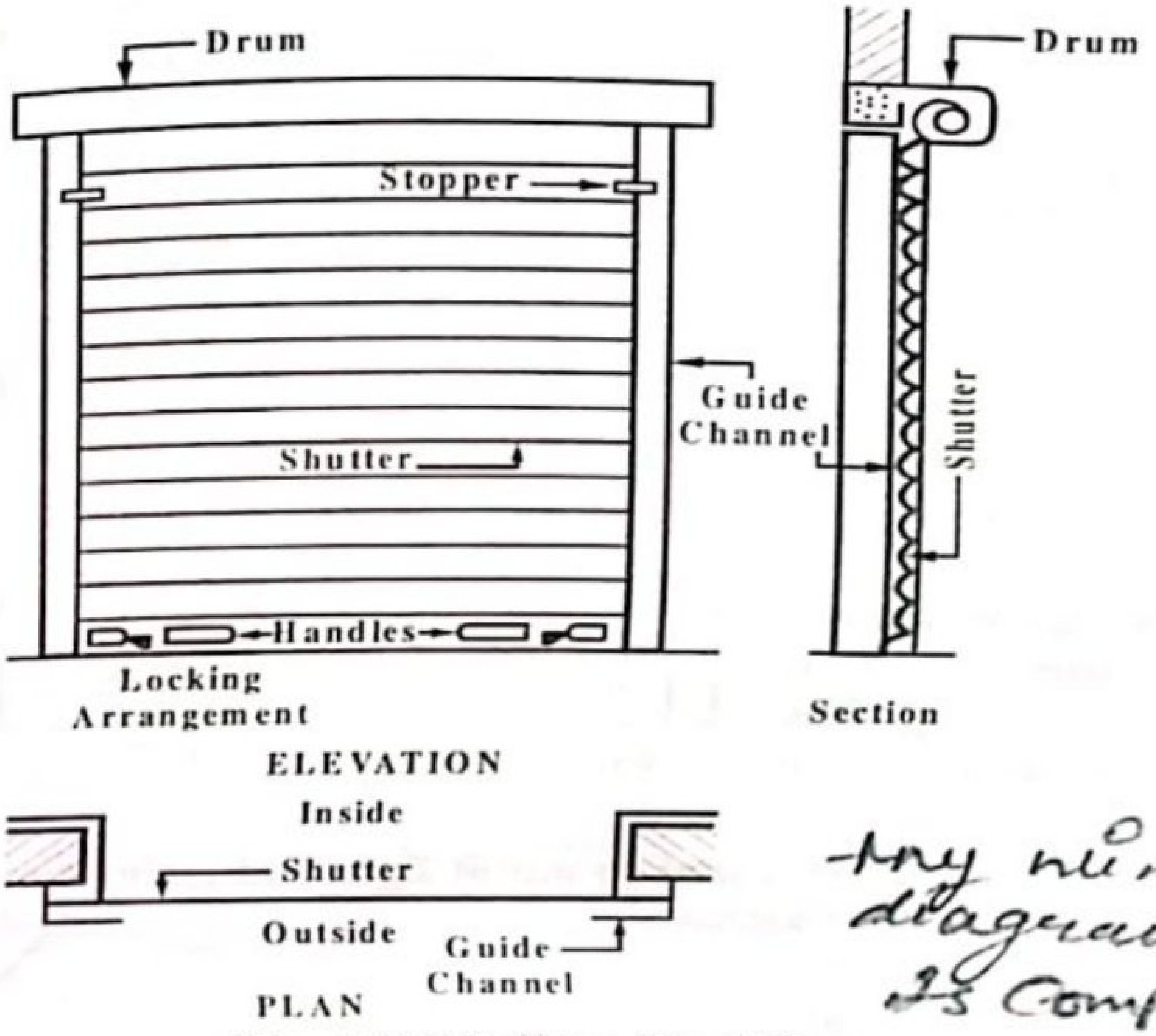


Fig. 1.55 Rolling Steel Door

Any window diagram with its component.

Q.104. Write short note on – Windows. ***(R.G.P.V., Nov./Dec. 2007)***

Ans. A windows is also a barrier secured in a wall opening. Windows consists of two parts as window frame and shutter. The window frames are fixed to the opening in the wall, by means of suitable hold fasts.The shutters are fixed to the window frames.

The function of the window is to admit light and air to the room and to give a outside view. Windows are also provided for insulation against heat and sound loss.

Size, shape, location and number of windows in a room depends upon the size of room, location of the room, utility of room, direction of wall and wind, humidity and temperature, exterior view and desire of Architect.

#***Q.105. Describe the types of windows.*** ***(R.G.P.V., June/July 2006)***

Ans. Following are the various types of windows –

(i) Louvered Windows – Like louvered or ventilated doors, windows also provide free passage of air and sufficient light even when closed. Moreover, these windows offer sufficient privacy and also provide protection against excessive daylight and glare inside buildings without affecting ventilation. But, because they harbour dust and are difficult to clean, they are only used for W.C. rooms in private and public buildings, workshops and schools, etc., where opaque glass louvers are used. The construction of these windows is similar to that of louvered doors. This type of window consists of a series of louvers (either of wood, glass or metal) either fixed or moving type, contained in a frame. For economical construction, the angle of inclination of louvers or blades to the vertical stile is usually kept 45°.

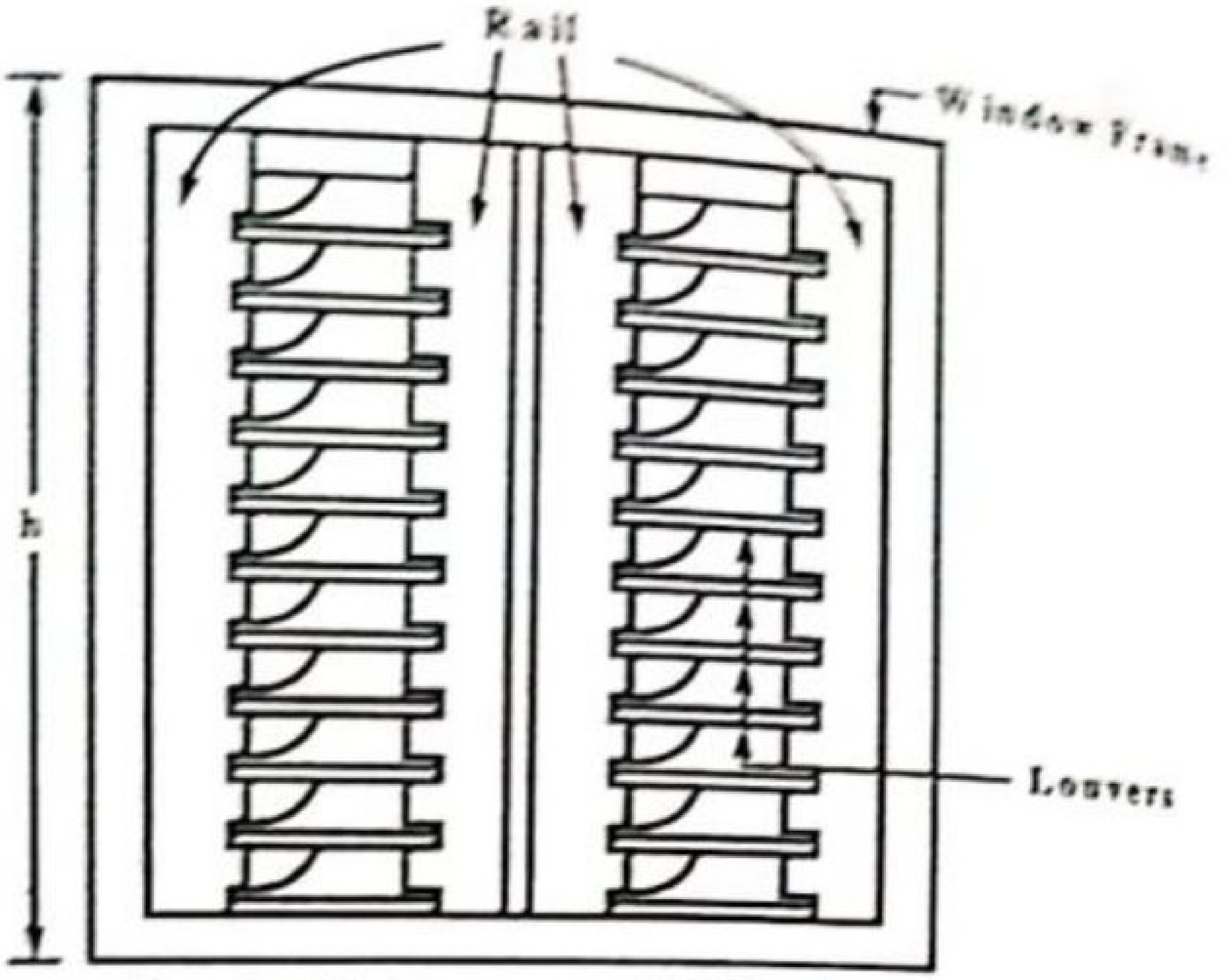


Fig. 1.56 Louvered Window

(ii) Dormer Windows – These are the vertical windows built on sloping sides of a pitched roof, as shown in fig. 1.57.

These windows are provided to admit light and air to the rooms or the enclosed space below the roof slopes. Incidentally, these windows add to the appearance of the building.

(iii) Gable Windows – These windows are provided in the gable ends of a pitched roof. They are used to admit light and ventilation inside the rooms as shown in figure 1.57.

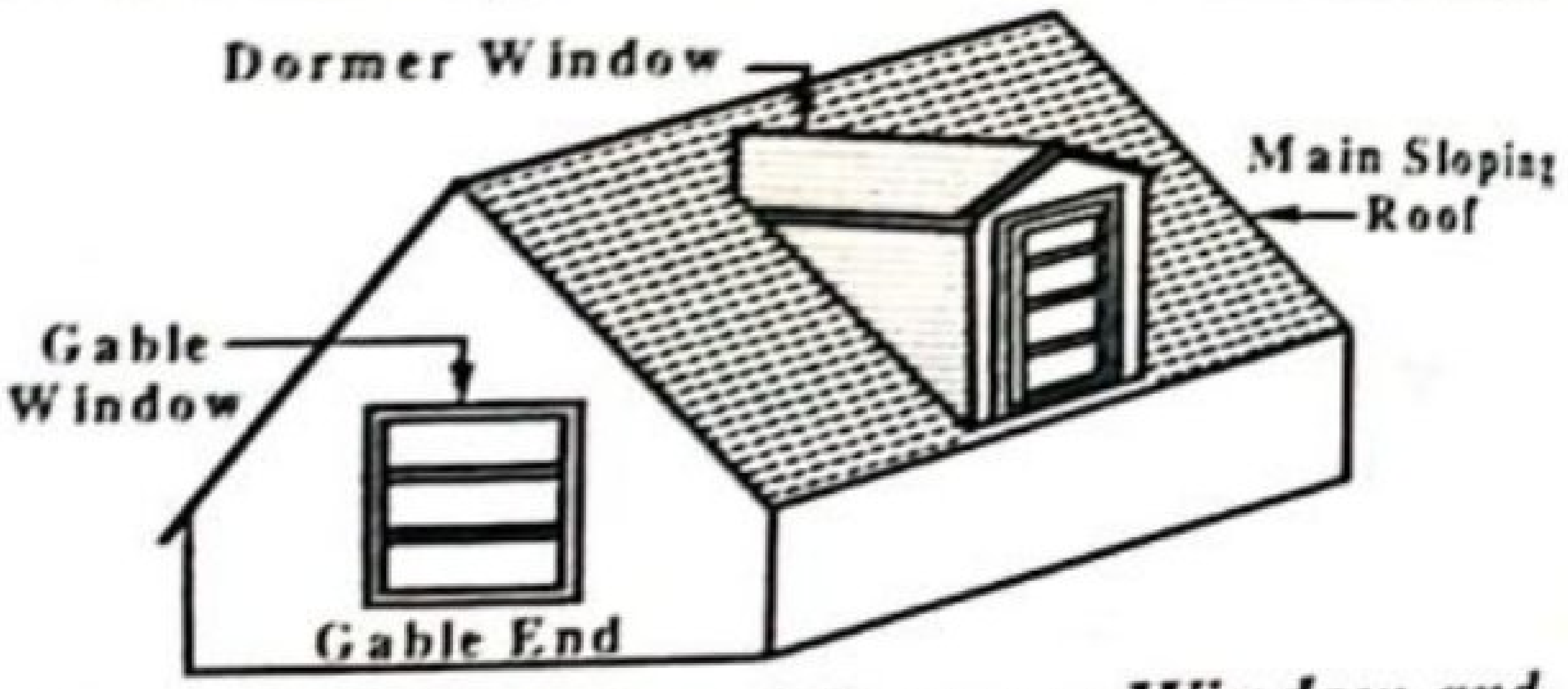
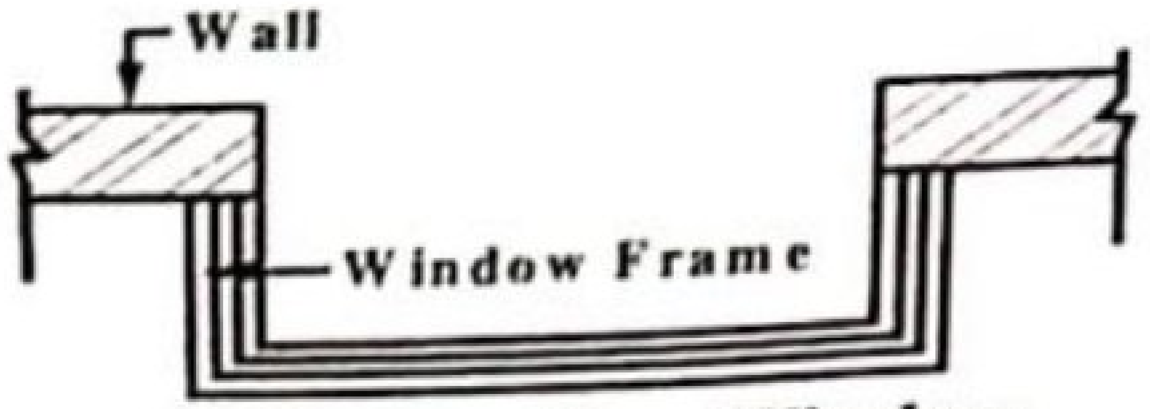
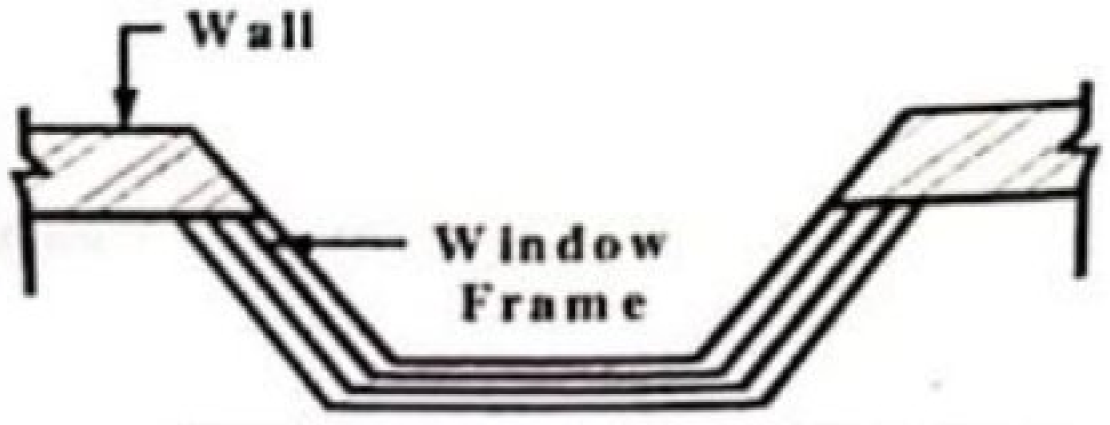


Fig. 1.57 Details of Dormer Window and Gable Window

(iv) Bay Windows – These windows project outside the external walls of a room, so as to form a projection known as a bay in a room. Such type of windows provide increased area of opening for admitting more light and ventilation from different directions. These windows also offer extra space in the room and improve the overall appearance of the building.



(a) Square Bay Window



(b) Splayed Bay Window

Fig. 1.58

These windows may be half square, splayed i.e., semi-hexagonal, semi octagonal or semi-circular in plan or any other shape.

The details of the bay window in plan are shown in fig. 1.58 (a) and (b). The projection of such a window may start from floor level or sill level.

(v) Clerestorey Windows – These windows are provided near the top of main roof as shown in fig. 1.59. The pivoted windows are used for this purpose. The clerestorey windows provide ventilation to the inside of the room as the front is blocked by the verandah. They also improve the appearance of building. The care should be taken to see that the upper part opens inside and the lower part opens outside. Otherwise the rain water will accumulate in the room.

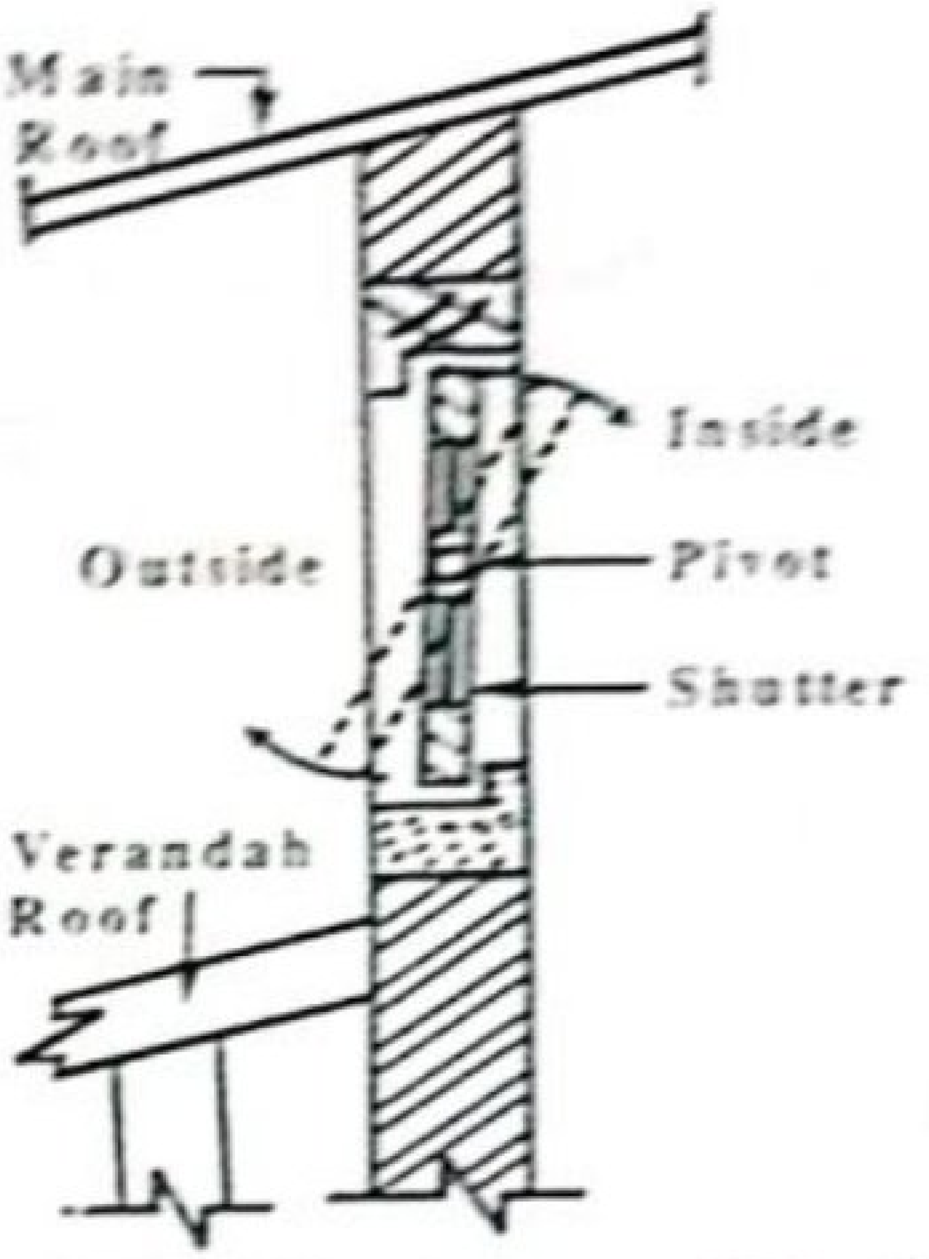


Fig. 1.59 Clerestorey Window

Q.106. List out various types of doors and windows with suitable sketch. ***(R.G.P.V., Dec. 2015)***

Ans. Refer Q.103 and Q.105.

Q.107. Draw a neat sketch of door and window and explain its components. ***(R.G.P.V., Dec. 2016)***

Ans. Refer Q.103 and Q.105.

Q.108. Define lintel and its functions.

Ans. Lintel is a horizontal member which is placed over an opening. It acts just like a beam. It transfer the loads, acting over the openings to the supporting walls.

Functions – There are various functions of lintels –

(i) They are provided over an opening to support the portion of the structure above it.

(ii) They act as a beam.

(iii) They support the load acting over the openings.

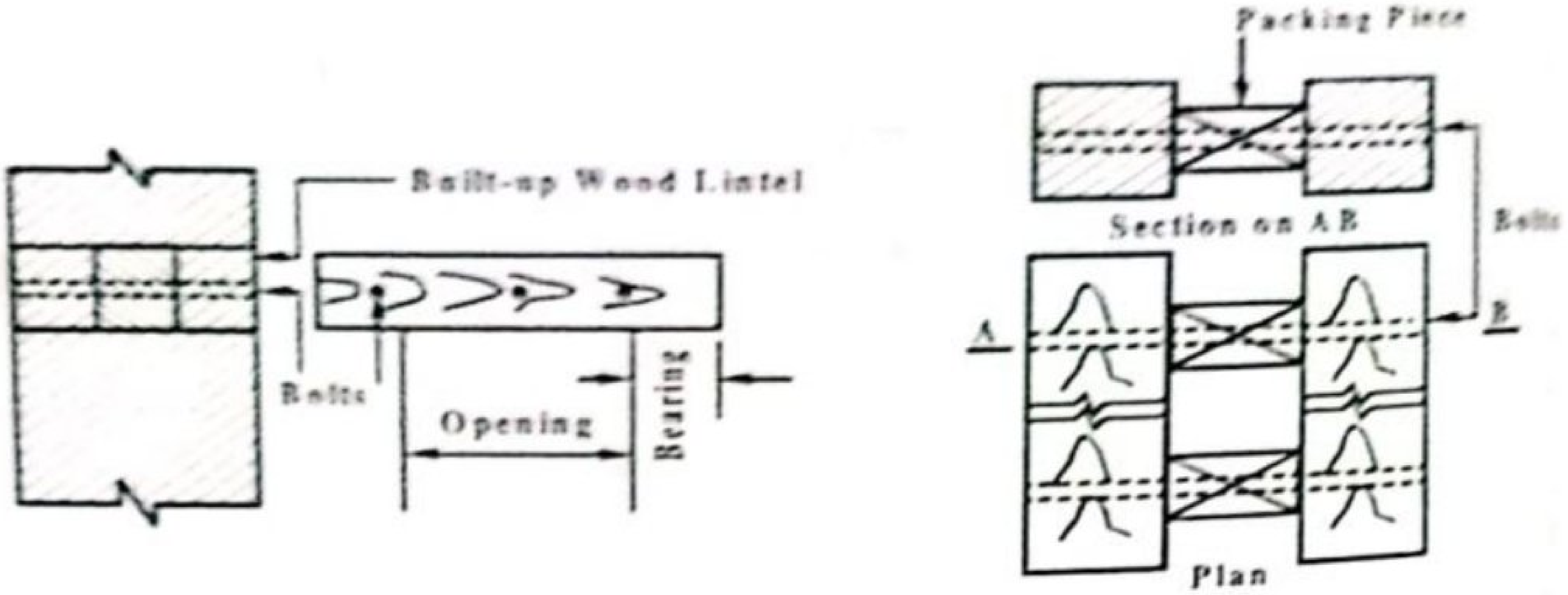
(iv) Arches provide architectural appearance.

(v) They provide openings for doors, windows, ventilators, cupboards, ward robes etc.

Q.109. What materials which are commonly used to construct lintel ?

Ans. There are various materials used to construct lintel as follows –

(i) Timber Lintel – They are made up from timber pieces those are placed over the openings. These were in use in olden days. They are not in common use these days. They are easily affected by white ants and other insects. These are the weak sections than stone and steel. See fig. 1.60.



(a) (b)

Fig. 1.60 Timber Lintel

(ii) ***Stone Lintel*** – They are made up from stone pieces those are placed over the openings. They may be in the form of single piece or more than one piece. They are very weak in tension so cannot be used on large spans. They may crack when subjected to the vibrations. See fig. 1.61.

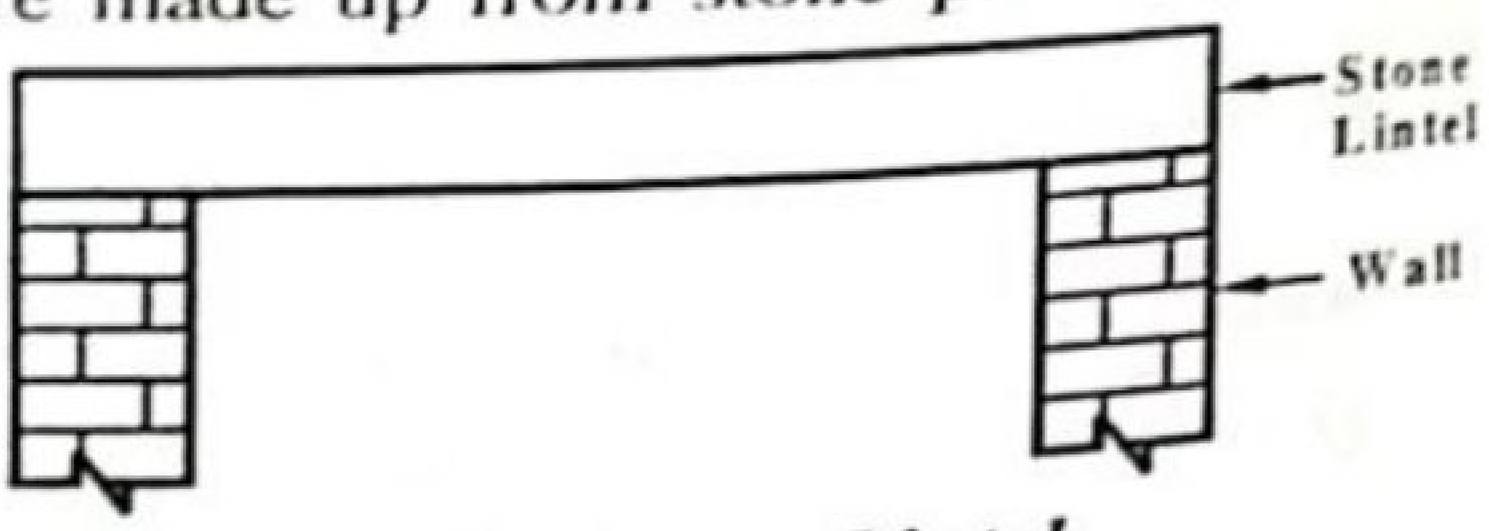
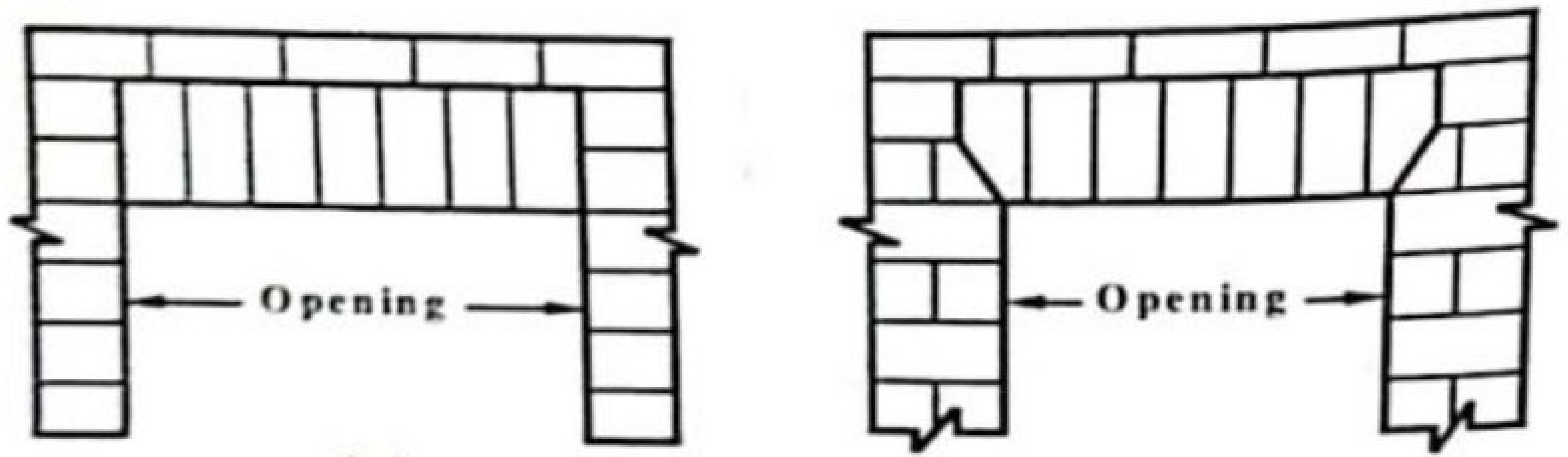


Fig. 1.61 Stone Lintel

(iii) ***Brick Lintel*** – They are made up from bricks those are generally placed on end or on edge. The bricks should be well burnt and free from cracks. These are weak in nature so that they are suitable up to span of 1m. See fig. 1.62.



(a) (b)

Fig. 1.62 Brick Lintel

(iv) ***R.C.C. Lintel*** – They are made up from reinforcement and concrete. The reinforcement is provided for resisting tensile stresses and concrete is provided for resisting compressive stresses. They are very suitable in modern construction. They may be cast in any shape and size. They may be used for long spans. They may be precast or cast in situ. See fig. 1.63.

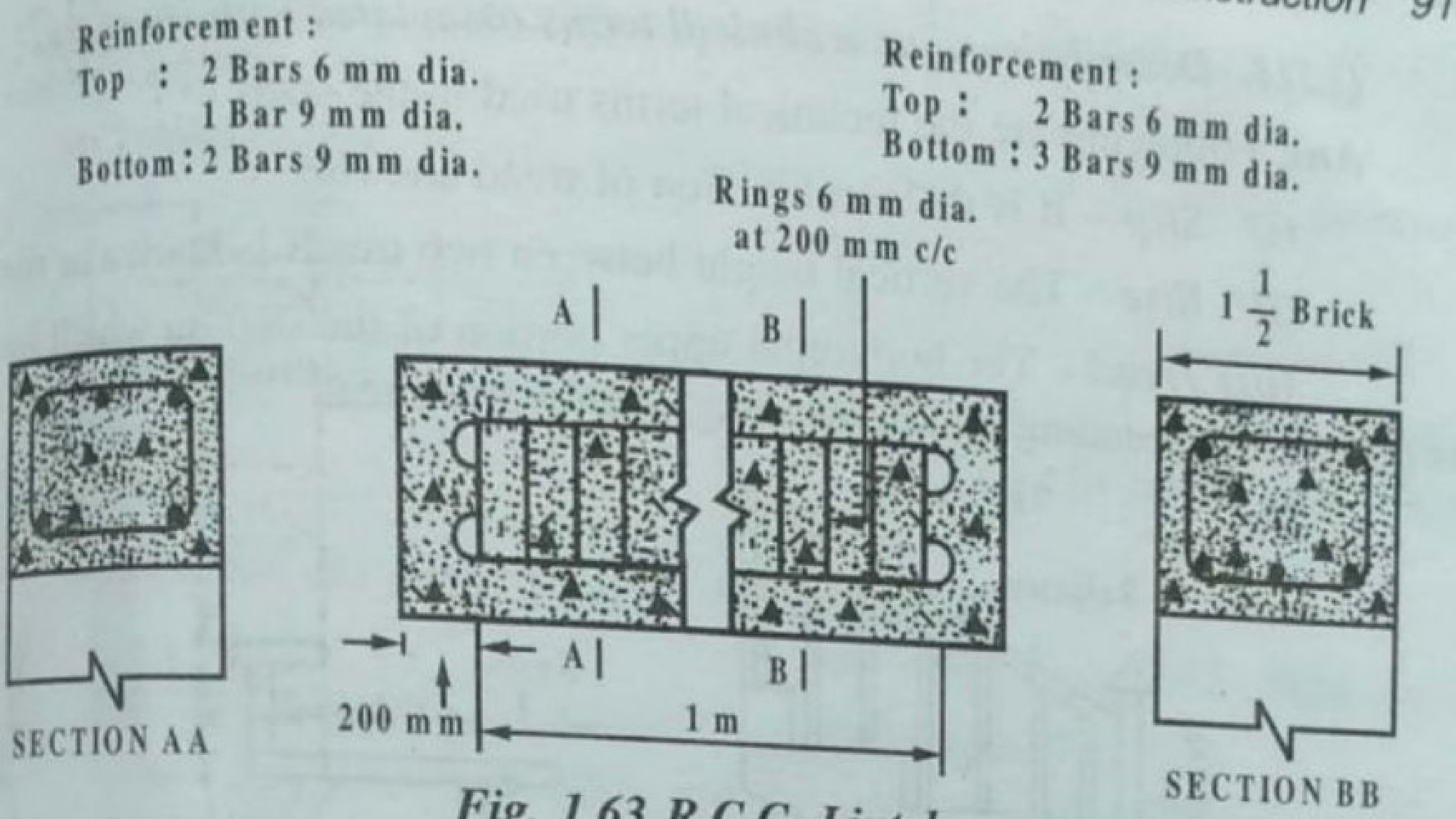


Fig. 1.63 R.C.C. Lintel

(*v*) ***Steel Lintel*** – They are made up from steel angles of rolled steel joist. Angle iron are used for small span and rolled steel joist are used for large spans. The steel joists may be used single or may be combination of two or three units. See fig. 1.64.

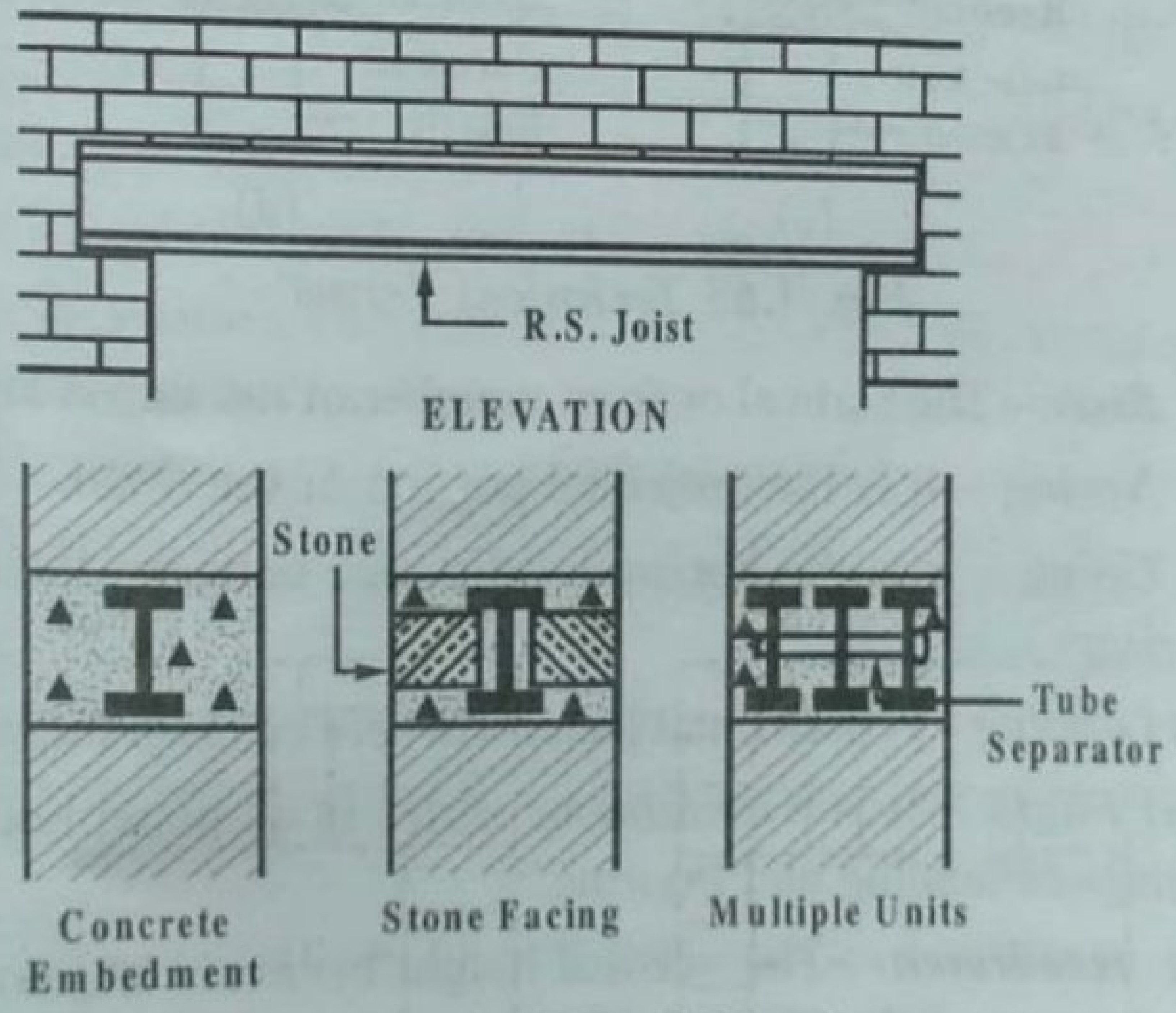


Fig. 1.64 Steel Lintel

STAIRCASES – TYPES AND THEIR SUITABILITY

#Q.110. Define staircase.

Ans. Stair is the structure having series of steps which provides the ascent and descent between the floors and the room in which stair is located is known as staircase.

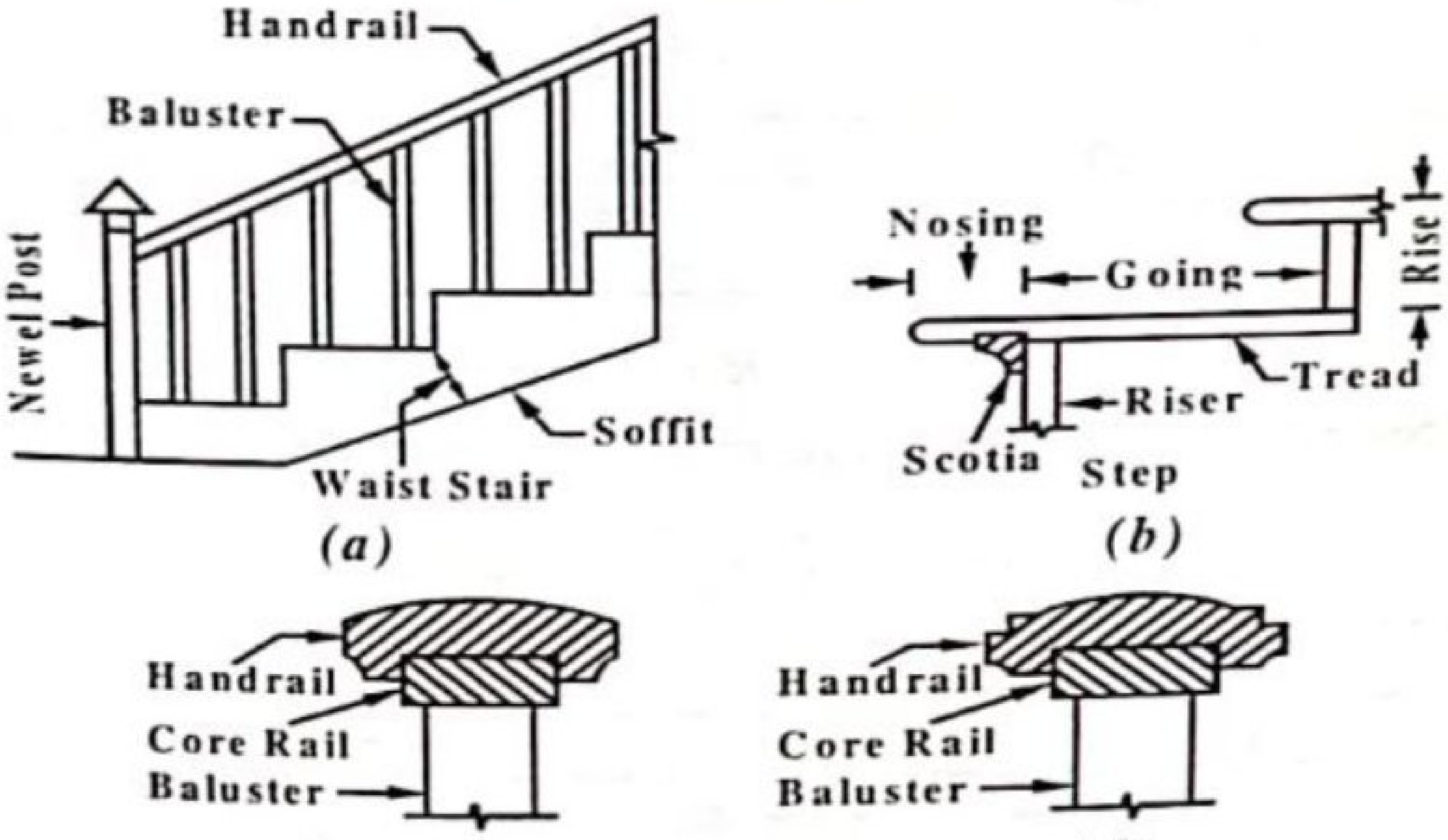
Q.111. Describe various technical terms associated with staircase.

Ans. Following are the technical terms used in the stairs –

(i) ***Step*** – It is the combination of tread and rise.

(ii) ***Rise*** – The vertical height between two treads is known as rise.

(iii) ***Tread*** – The horizontal upper portion of the step on which foot is placed for ascending and descending is known as tread.



(a) *(b)*

(c) *(d)*

Fig. 1.65 Technical Terms

(iv) ***Riser*** – The vertical or front member of the step is known as riser.

(v) ***Nosing*** – It is the projected portion of the tread.

(vi) ***Going*** – It is the horizontal distance between the faces of two consecutive risers.

(vii) ***Landing*** – A horizontal plateform between two successive flights.

(viii) ***Flight*** – It is a continuous series of steps without any break, between landings or landing and flooring.

(ix) ***Headroom*** – The vertical height between the nosings of one flight and the bottom of the flight, is known as headroom.

(x) ***String*** – The inclined member of a stair which supports the ends of steps is known as string.

(xi) ***Handrail*** – It is the inclined rail provided over balustrades. The rail is parallel to the string.

(xii) ***Baluster*** – It is the vertical member fixed between string and handrail.

(xiii) ***Balustrade*** – The combined frame work of handrail and baluster.

(xiv) Pitch – The angle of inclination of the stair with the floor is known as pitch.

(xv) Scotia – It is an additional moulding provided under the nosing to beautify the step.

(xvi) Soffit – The under surface of a stair is known as the soffit.

Q.112. What are the requirements of a good stair ? Discuss them in detail.
(R.G.P.V., Dec. 2013)

Or

Enumerate the requirements of good stairs.
(R.G.P.V., Dec. 2002, 2004, 2005)

Ans. A good stair should have following characteristics –

(i) It should be of sufficient size not too large neither too small.

(ii) The steps of the stair should be sufficient wide.

(iii) It should be near by to the all the rooms of the building.

(iv) It should be strong and durable.

(v) The height of the rise should not be more than 20 cm.

(vi) Inclination of stair should not be less than 25° and more than 45°.

(vii) Minimum 3 number of steps should be in a flight and maximum should not be more than 15.

(viii) It should have sufficient landing area.

(ix) It should be located centrally in residential building and near the main entrance in public buildings.

(x) It should be provided with handrails.

Q.113. Describe salient points considered while locating staircase in a building.
(R.G.P.V., June 2005, 2009)

Or

Explain about the various considerations for selecting location of staircase.
(R.G.P.V., June 2012)

Ans. Following are the sailent points to be considered while locating stair-case in a building –

(i) The stairs should be located near the main entrance in case of public buildings.

(ii) The stairs should be located centrally so as to have easy access from all the rooms without disturbing the privacy of rooms.

(iii) The stairs should be so located that they are well-lighted and well ventilated.

(iv) The stairs should be so located they have convenient and spacious approaches.

(v) The stairs should be so located as to provide easy access to the occupants of the building.

(vi) The stairs should be so located as to easily visible from each part of the building in case of public building.

(vii) In case of big buildings, these should be more than one stairs.

Q.114. What are various types of staircases commonly used ? Sketch any three types giving their advantages.

(R.G.P.V., Jan./Feb. 2006, June/July 2006, Dec. 2006, June 2009, Sept. 2009)

Ans. The stairs are classified as follows –

(i) Straight stairs
(ii) Turning stairs
(iii) Circular or helical or spiral stairs.

(i) Straight Stairs – In this type of stairs, all steps are lead in one direction. There may be one or more flights, they are used only when the space available for stairs is narrow in width. See fig. 1.66.

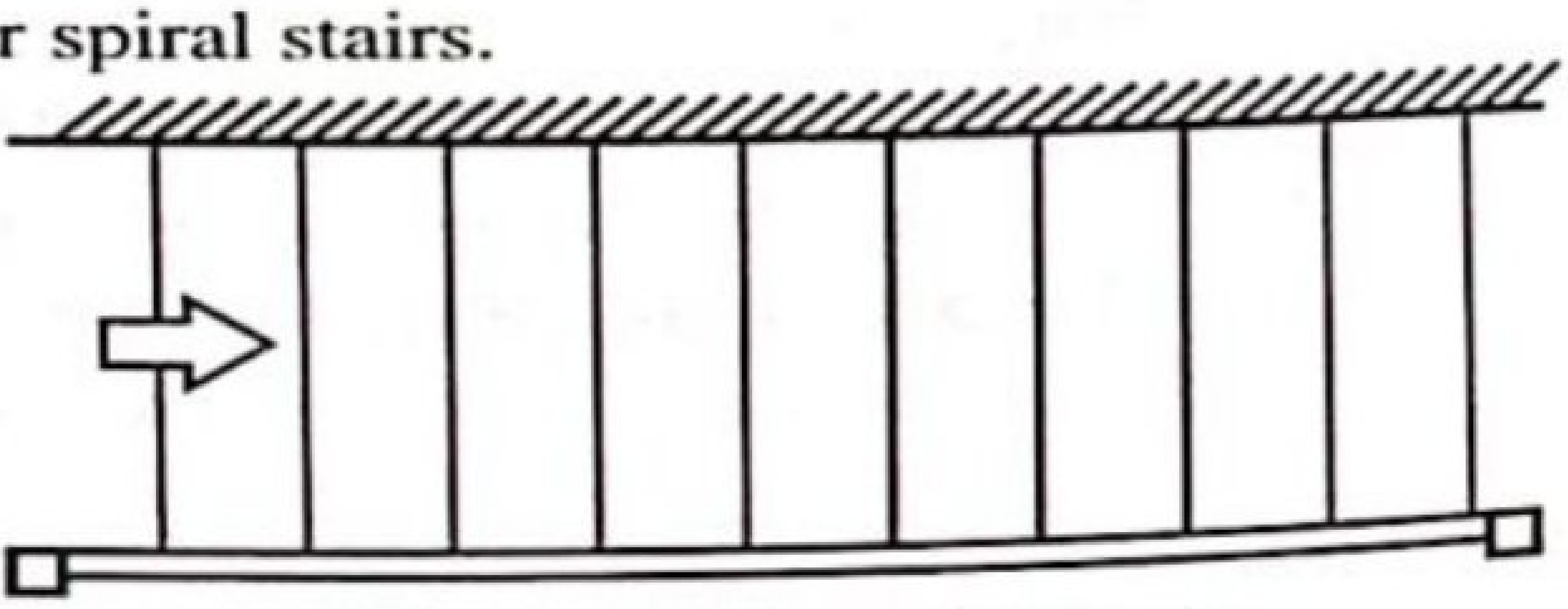
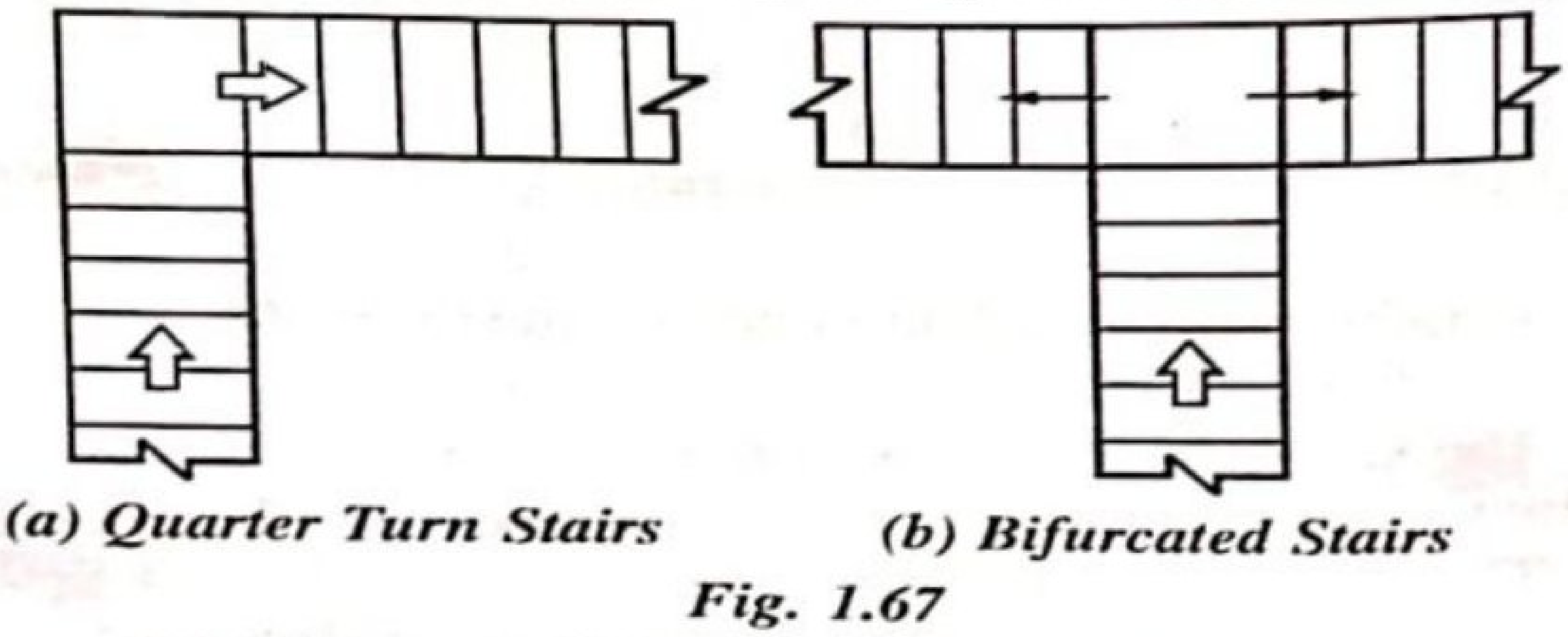


Fig. 1.66 Straight Stairs

(ii) Turning Stairs – In this type of stairs flight take turns. There are different type of stairs –

(a) Quarter Turn Stairs – A stair turning through one right angle is known as quarter turn stair. [See fig. 1.67 (a)].



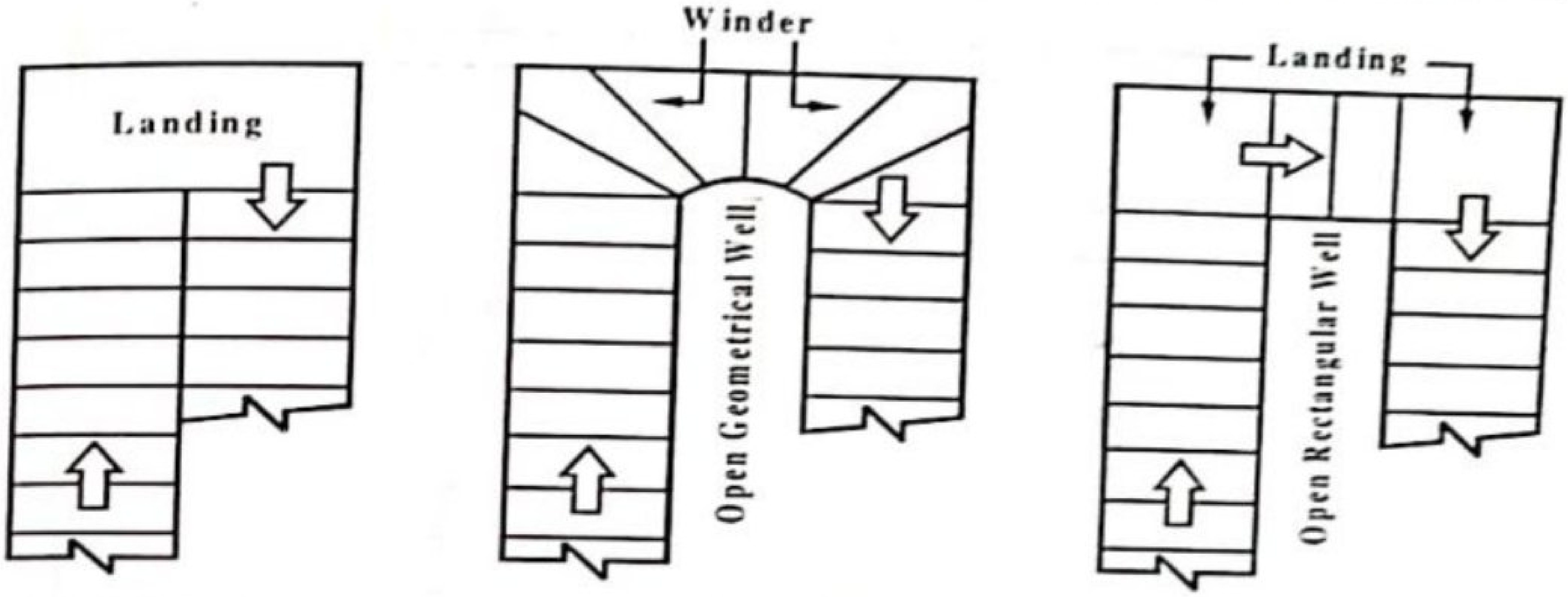
(a) Quarter Turn Stairs

(b) Bifurcated Stairs

Fig. 1.67

(b) Bifur-cated Stairs – When quarter turn stair is branched into two flights at a landing, it is known as bifurcated stair. [See fig. 1.67 (b)].

(c) Half Turn Stairs – When stair turn through 180°, it is known as half turn stair. They are of open newel or dog-legged type. (See fig. 1.68).



Dog-legged Stair

Open Newel Stair

Fig. 1.68 Half Turn Stairs

(iii) Circular or Helical Stairs – In this type of stairs all the steps are radiate from a common newel post or centre. They are made up from, wooden, steel or concrete. It is provided where the space available is less. (See fig. 1.69).

If space available is less then, ***circular*** or ***helical stairs*** will be suggested to construct.

If space available is large then, ***bifurcated*** or ***open newel stairs*** will be suggested to construct.

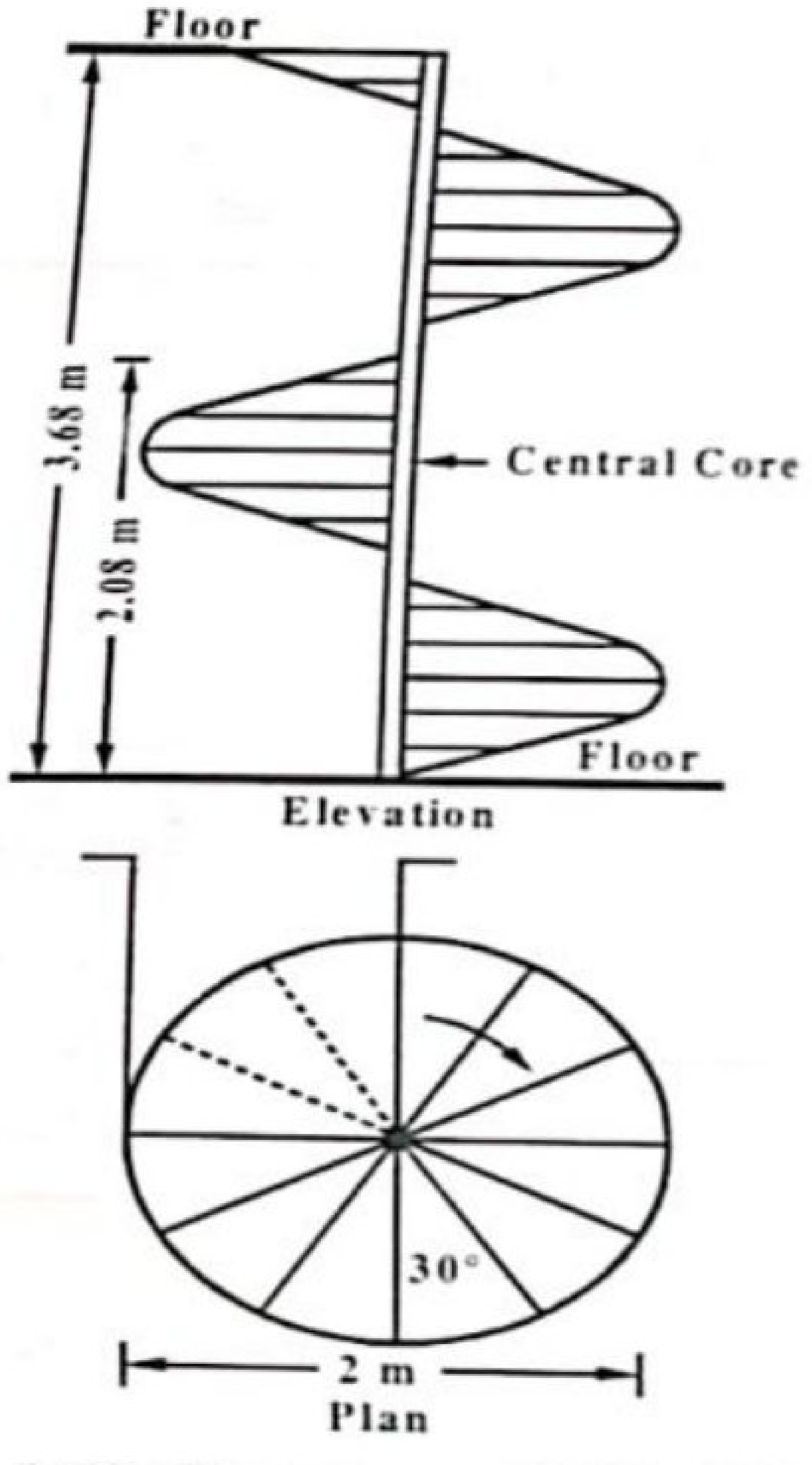


Fig. 1.69 Circular or Helical Stairs

Q.115. State the circumstances under which you use the following types of stairs –

(i) Dog-legged stair

(ii) Spiral stair.

(R.G.P.V., June 2015)

Ans. (i) Dog-legged Stair – The dog-legged stair flights are in opposite direction and no space is provided between the flights in plan. This type of stair is generally recommended for residential buildings. The dog-legged name is given to its appearance in sectional elevation. It comes under the category of newel (or solid newel). Stairs in which newel posts are provided at the starting and end of each flight.

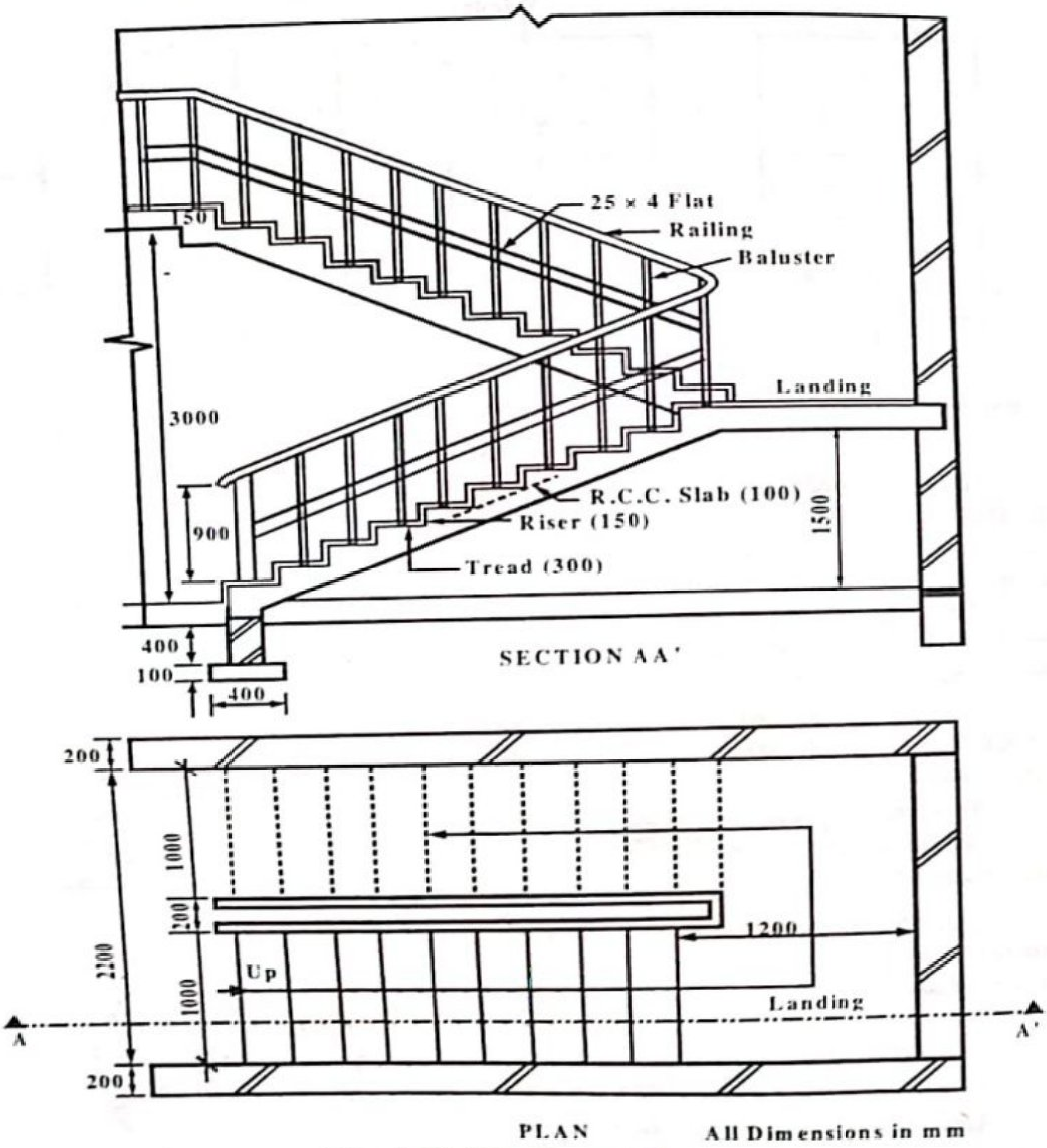


Fig. 1.70 Dog-legged Stairs

(ii) Spiral Stair – Refer Q.114 (iii).

Q.116. Mention the various factors considered while choosing location of stair in a building. Draw neat sketch of Dog-legged stair showing various components of the stair. ***(R.G.P.V., June 2014)***

Ans. Refer Q.113 and Q.115.

Q.117. Draw the neat sketches of the following –
(i) King post roof truss (ii) Open newel stairs.
(R.G.P.V., Dec. 2012)

Ans. Refer Fig. 1.49 (Q.101) and Fig. 1.68 (Q.114).

Q.118. How treads and risers are proportioned ?

Ans. The procedure for determining the number of treads and risers is as follows –

(i) The positions of first and last risers are determined with regard to the positions of doors, windows, verandahs, etc.

(ii) A convenient height of the riser is assumed.

(iii) Number of risers = $\frac{\text{Total height of floor}}{\text{Height of riser}}$

(iv) Number of treads in a flight = Number of risers – 1.

This is due to the fact that the surface of the upper floor forms the tread for the top step.

For instance, let us suppose that the height of floor is 3.50 m. Assume a riser of 140 mm.

Then, No. of risers = $\frac{3.50}{0.14} = 25.$

No. of treads for stair with single flight = (25 – 1) = 24.

No. of treads for stair with double flight = (25 – 2) = 23.

Depending upon the space available for staircase, the type of stair is selected.

In order to make the ascent and descent easy, the treads and risers of a stair should be suitably proportioned.

Following rules-of-thumb are commonly used for obtaining a satisfactory proportion of the tread and riser of a step –

(i) (Rise in cm) + (going in cm) = 40 to 45.

(ii) (Rise in cm) × (going in cm) = 410 to 450 approximately.

(iii) (2 × rise in cm) + (going in cm) = 60 approximately.

(iv) Take rise = 140 mm and going = 300 mm as standard.

Then, for each 20 mm subtracted from the going, add 10 mm to the rise. Thus other combinations of rise and going would be –

150 mm × 280 mm, 160 mm × 260 mm, 170 mm × 240 mm.

The staircase in a residential building should not have a rise of more than 230 mm and a going of less 230 mm. For public buildings, it is desirable to have a rise of not more than 180 mm and a going of not leSs than 270 mm. the winder the going,the less should be the riser and the greater the rise, the less should be the going. For a winder,the width of going is measured at a distance of 450 mm from the inside or the small end of the tread.

NUMERICAL PROBLEMS

Prob.1. Design a staircase for G + 2 storey residential building. The clear height of ground floor and two upper floor is 3.30 m and 3.10 m respectively. Also draw longitudinal section of the designed staircase. (R.G.P.V., Dec. 2011)

Sol. Design a dog-legged staircase.

Assume thickness of floor slab = 120 mm. Assume height of riser = 180 mm

For Ground Floor –

Then, no. of riser for ground floor

$$= \frac{\text{Total height of floor}}{\text{Height of riser}}$$

$$= \frac{3300+120}{180} = \frac{3420}{180} = 19$$

To provide the suitable headroom below landing level, provide 12 risers in the first flight and 7 risers in the second flight.

Assume a tread of 230 mm

So as number of tread in the first flight will be 11

For First and Second Floor –

No. of risers for first and second floor

$$= \frac{\text{Total height of floor}}{\text{Height of riser}}$$

$$= \frac{3100+120}{180} = \frac{3220}{180}$$

$$= 17.89 \approx 18$$

So as 9 no. of risers will be in the each flight.

Assume a tread of 230 mm

So as number of tread in the each flight will be 8.

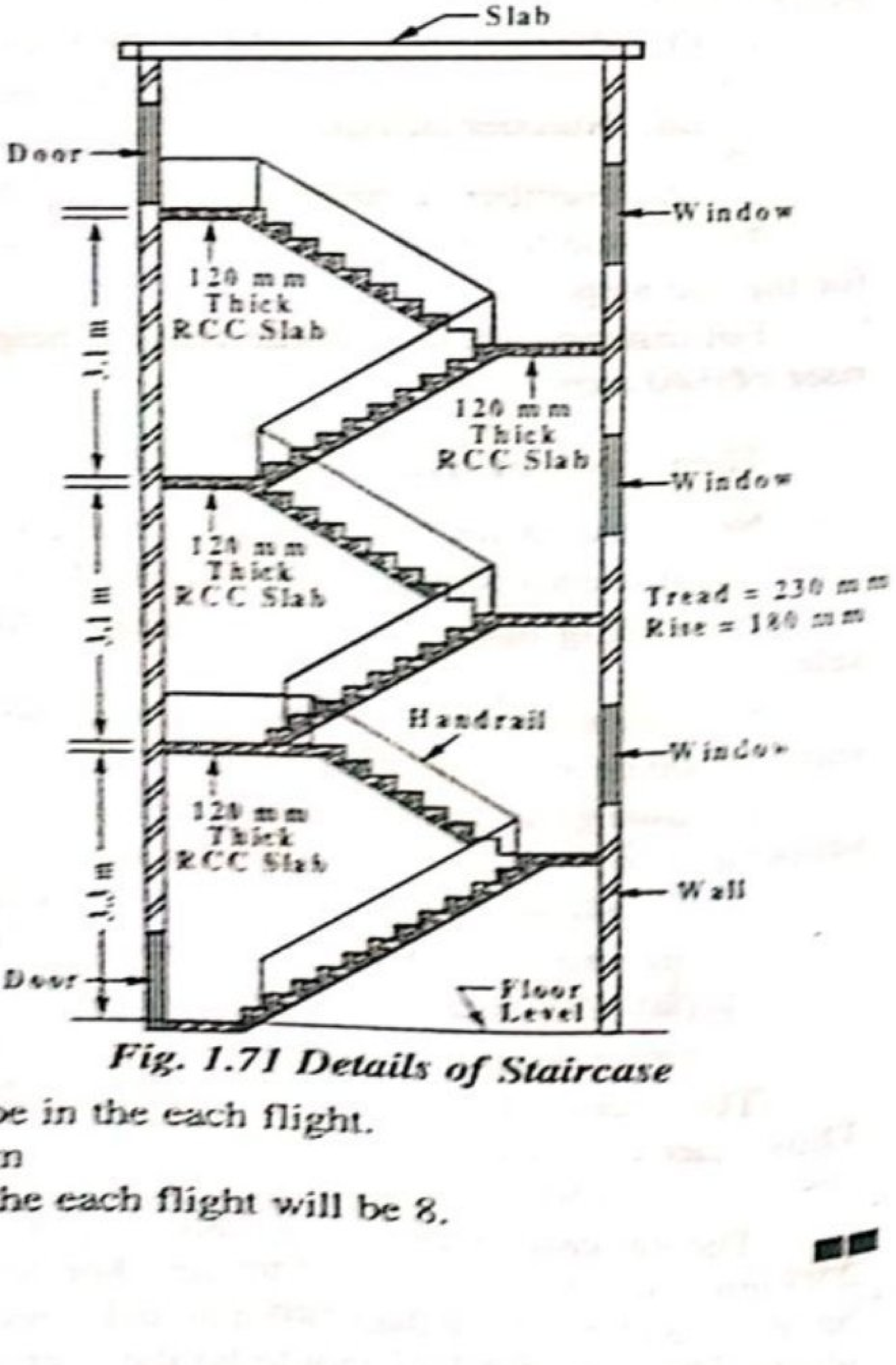


Fig. 1.71 Details of Staircase

UNIT 2

SURVEYING AND POSITIONING

INTRODUCTION TO SURVEYING INSTRUMENTS

Q.1. Define surveying. State uses of surveying.
[R.G.P.V., June/July 2006, June 2008 (O)]

Ans. Surveying is the science of determining the relative positions of points on, above or beneath the surface of the earth by means of direct or indirect measurements of distance, direction and elevation.

Surveying is the first step for execution of any Civil Engineering structure which may be any building, dam, tunnel, roads, railway lines, transmission lines, etc.

Object of surveying is the demarcation of boundaries of land and to prepare map and plan. That means the practical importance of surveying cannot be underestimated. In the absence of accurate maps, it is impossible to layout the alignments of roads, railways, canals, tunnels etc.

Before execution of any work, it is necessary to fixup the boundaries of the land and then the plan of the structure is prepared, for which an engineer must have thorough knowledge of principles and methods of surveying .

Q.2. State primary division of surveying. (R.G.P.V., June 2003)

Ans. Primary division of surveying made on the basis, whether the curvature of the earth is taken in account or not. The actual shape of the earth is an oblate spheroid. The length of the polar axis is shorter than the equatorial axis, but this difference is very small. So as the earth is assumed as an sphere for student's understanding.

Because of the curvature of the earth's surface, the measured distances on earth's surface are actually curved but, when the distances are small, there is no significant difference between the curved distances and corresponding straight line distance thus the curvature of the earth can be neglected.

Surveying is thus primarily divided into two types –

(i) Plane surveying (ii) Geodetic surveying.

(i) Plane Surveying – Surveying in which, surface of the earth is assumed as a plane and the curvature of the earth is ignored is known as plane surveying.

As the plane surveying extended only over the small areas, the line connecting two points is treated as straight line. The angle between such lines are taken as plane angles. All triangles formed by these lines are considered as plane triangles. It is less accurate and inferior to geodetic survey. In dealing with plane surveying, the knowledge of plane trigonometry and geometry is only required.

(ii) Geodetic Surveying – It is the type of surveying in which the curvature of the earth is taken into account and a very high standard of accuracy is maintained.

As the surveys extend over large areas, the lines joining any two points on the surface of the earth are treated as arcs. The angles between the curved lines are treated as spherical angles. Triangle formed by joining three lines is treated as spherical triangle. This survey is much more accurate and superior than plane surveying.

Fig. 2.1 shows three points A, B and C on the surface of the earth. The lines AB, BC and CA are the arcs of great circle passing through the centre of the earth. A great circle is formed by the intersection of a plane passing through the centre of the earth. A spherical triangle is formed by joining three points A, B and C. In fig. 2.1 chord AB, BC, CA makes plane triangle whereas α_0, β_0, γ_0 are spherical angles.

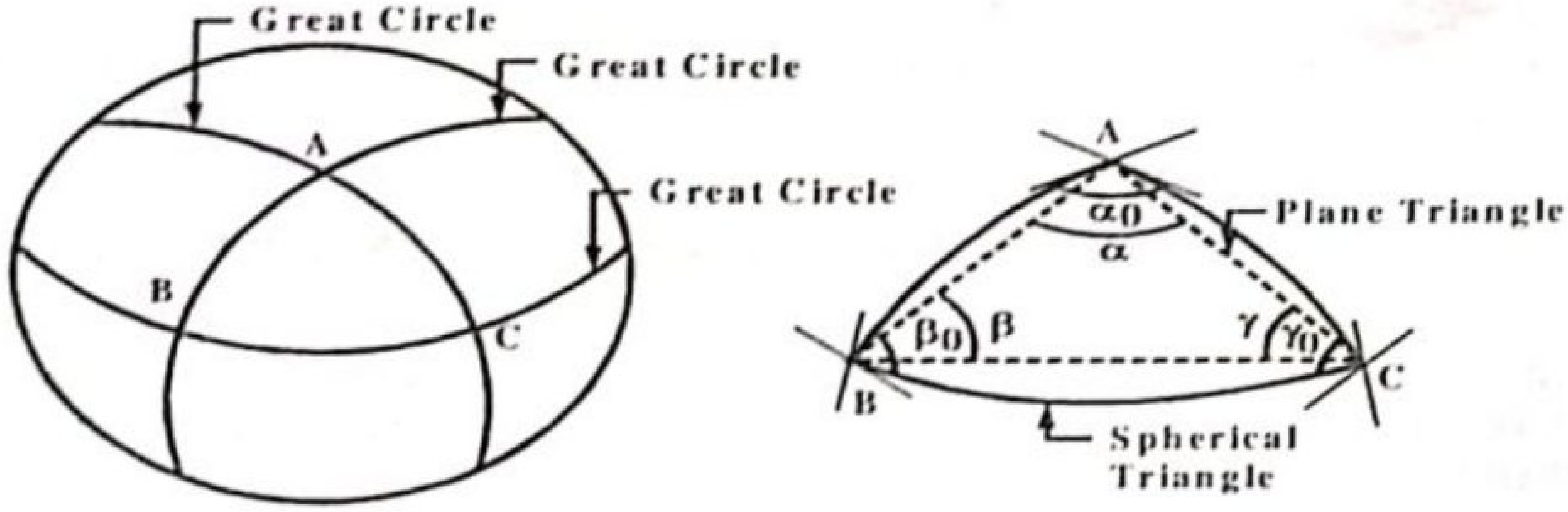


Fig. 2.1 Plane and Geodetic Surveying

The length of an arc having 12 km length is only 1 cm greater than the length of that respective chord. Also area of 196 km^2 is treated as plane survey because, the difference between sum of angles of spherical triangle ($\alpha_0 + \beta_0 + \gamma_0$) and sum of angles of plane triangle ($\alpha + \beta + \gamma$) is only 1" for that area.

Q.3. Differentiate between plane and geodetic surveying.

Ans. Differences between plane and geodetic surveying are given below –

S.No.	*Plane Surveying*	*Geodetic Surveying*
(i)	In this surveying, surface of the earth is assumed as a plane.	In this surveying, surface of the earth is assumed as an arc.
(ii)	In this surveying, curvature of the earth is not taken into account.	In this surveying curvature of the earth is taken into account.
(iii)	Length up to 12 km is treated as plane surveying.	Length more than 12 km is treated as geodetic surveying.
(iv)	Area up to 196 km^2 is treated as plane surveying.	Area more than 196 km^2 is treated as geodetic surveying.
(v)	It is less accurate and inferior.	It is more accurate and superior to plane surveying.

Q.4. Write down classification of survey.

Ans. Classification of survey based upon –

(i) Nature of the field survey
(ii) Purpose of survey
(iii) Instruments used
(iv) System of survey.

(i) Classification Based Upon the Nature of the Field Survey – These include the following –

(a) Land Surveying – It include the following –

(1) Topographical Survey – It consist of determining horizontal and vertical location of certain points by linear and angular measurements. These topographical features are such as hill, rivers, lakes, dams, railways and roadways.

(2) Cadastral Surveys – These surveys are carried out to fixing up property lines, also made to fix up the boundaries of municipalities, corporations and cantonments.

(3) City Surveys – These surveys are carried out to construct the roads, parks, water supply, sewer and other constructional works for any developing township.

(b) Hydrographic Surveys –These surveys are carried out on the surface of water. It deals with bodies of water for purpose of water supply, navigation etc. These are useful for measuring discharge of streams and prediction of tides, as well as for determination of mean sea level and depth of water.

(ii) Classification Based on the Purpose of the Survey – These include the following –

(a) Engineering Survey – These surveys are carried out for determining quantities of sufficient datas for designing engineering works, such as roads, reservoirs, water supply etc.

(b) Military Survey – These surveys are carried out for preparation of maps of the military importance.

(c) Mine Survey – These surveys are carried out for exploring the minerals, those are under the surface of the earth, i.e. coal, copper, gold etc.

(d) Geological Survey –These surveys are carried out to find out the composition of the earth crust, i.e. different states of rocks of the earth crust.

(e) Archaeological Survey – These surveys are carried out to prepare maps of ancient culture.

(iii) Classification Based on Instrument Used – These include the following –

(a) Chain Survey – It is that type of surveying in which only linear measurements are made in the field with the help of chain or tape.

(b) Compass Survey – Chain surveying can be used when the area to be surveyed is small. However when large areas are involved, compass survey is used. The method of determining directions of survey lines by compass and their length by chain is known as compass survey.

(c) Theodolite Survey – An instrument used for measuring horizontal and vertical angles is known as theodolite and method of determining horizontal and vertical angles is known as theodolite survey.

(iv) Classification Based Upon System of Survey –These includes the following –

(a) Triangulation Survey – In which the whole area is divided into series of triangles and length of one side of a triangle and all included angles of triangles are measured.

(b) Traverse Survey –This is the type of survey in which the lengths and directions of all the sides are measured with the tape and angle measuring instrument respectively.

Q.5. What are the fundamental principles of surveying ?

Ans. There are two basic principles of surveying –

(i) Always work from the whole to the part

(ii) Location of a point by measurement from two control points.

(i) Always Work From The Whole to the Part – This principle can easily be explained by taking a very simple case of measuring a straight length say 10 cm. It will be advisable to measure the length in a single stretch. But if the length is measured in short lengths of say 1 m, there are chances of error, and will accumulated. Similarly, in case of closed traverse survey, the surveyor should establish firstly the large framework and afterwards, he should establish the small frameworks.

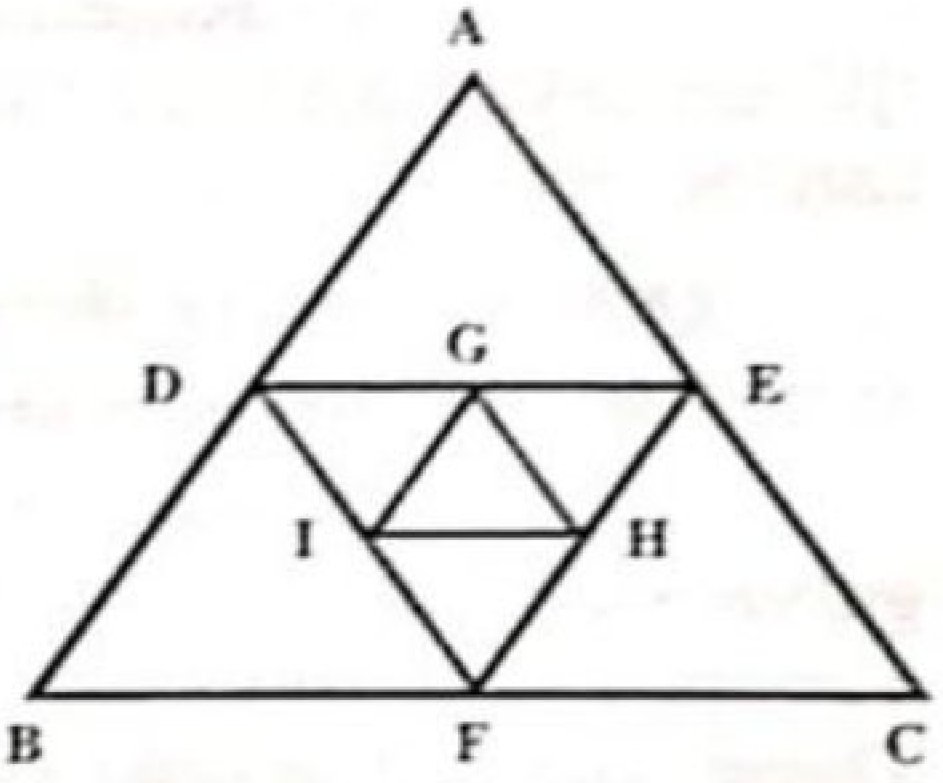


Fig. 2.2

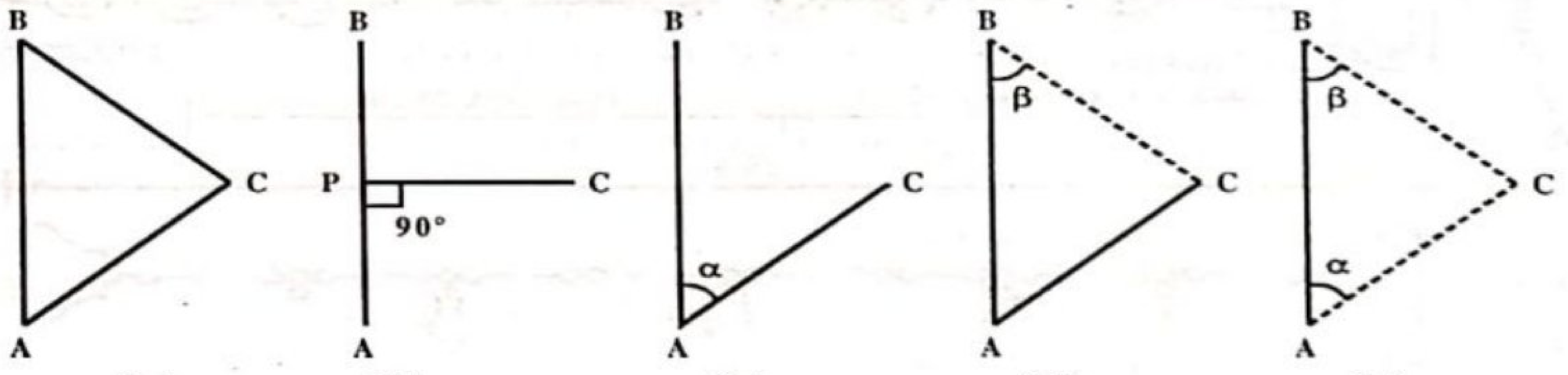
For illustration, let us consider three points A, B and C which form the large main framework ABC. These points are located with a very high standard of accuracy by measuring the distances AB, BC, CA. The interior small framework DEF can be established by measuring distances DE, EF, FD. The smallest framework GHI can also be established in the same way. These both small framework requires lower standard of accuracy.

(ii) Location of a Point by Measurement From Two Control Points – Two points of reference A and B are selected and the length AB is accurately measured on the field. Thus line AB can be plotted to a suitable scale on the paper. Now the position of any point "C" can be determined by following different methods –

(a) Referring to fig. 2.3 (a), lengths AC and BC are measured by swinging arcs, the position of point "C" can be determined. This method is generally used in chain survey.

(b) Referring to fig. 2.3 (b), a line CP perpendicular to AB is measured and then by measuring the distance AP, the position of point "C" can be determined.

(c) Referring to fig. 2.3 (c), angle α and distance AC are measured. Then plotting the angle 'α' by a protractor and extending the length up to AC, the position of point "C" can be determined.



(a) *(b)* *(c)* *(d)* *(e)*

Fig. 2.3 Location of a Point by Measurement From two Control Points

(d) Referring to fig. 2.3 (d), angle 'β' and distance AC are measured. Then by plotting angle 'β' by protractor and swinging the arc of length AC, the position of point 'C' can be determined.

(e) Referring to fig. 2.3 (e), the angular measurements 'α' and 'β' are taken and plotting these angles by protractor, the position of point 'C' can be determined.

Q.6. What are the different instruments used for linear measurements ?

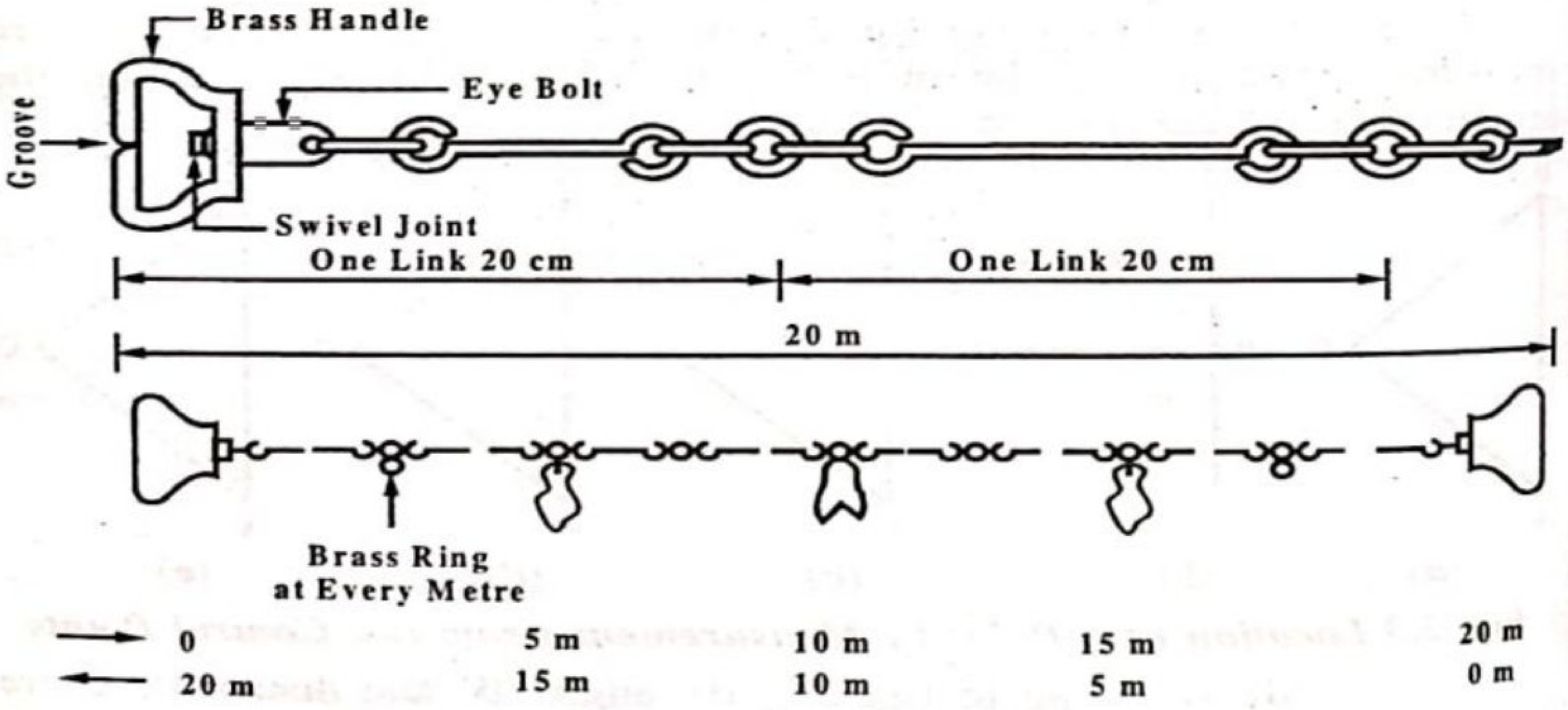
Ans. Following are the instruments used for linear measurements –

(i) Chain – Chain consists of a number of large links madeup of galvanised mild steel wire of 4 mm diameter. End of these large links is bent into a loop. Large links are connected to each other by three small circular rings. These connecting links provide flexibility to the chain. Brass handles are provided at each end of the chain, with a groove in the middle to facilitate holding of an arrow. The radius of the groove is equal to the radius of the arrow. The length of the link is the distance from the centre of the connecting central ring to the centre of the next connecting ring, and it is 200 mm. The overall length of the chain is from the outside of one handle to the outside of the other handle.

Following are the various types of chains in common use –

(a) Metric chain (b) Gunter's chain or surveyor chain
(c) Engineer's chain (d) Revenue chain.

(a) Metric Chain – These are generally 5 m, 10 m, 20 m and 30 m in length, having 25 links, 50 links, 100 links, 150 links respectively. The length of the each link is 200 mm. The links are madeup of galvanised mild steel wire of 4 mm diameter. The length of chain is marked on both the handles, provided at the end of the chain. Fig. 2.4 shows the details of a 20 m metric chain.



20 m Chain (I.S.I)

Fig. 2.4 Metric Chain

Metallic tallies are fixed at various points of the chain i.e. 5 m, 10 m, 15 m, 20 m, for quick and easy reading of the chain.

Small brass rings are provided at every one metre length except where the tallies are attached. For 20 m long and 30 m long chains, small brass rings are provided at every metre length, and tallies are provided at every 5 m length. Fig. 2.4 shows the shape of the tally, provided at every 5 metre length.

(b) Gunter's or Surveyor's Chain – It is 66 ft. long and it is divided into 100 links. Each link having length of 0.6 ft.

(c) Engineer's Chain – It is 100 ft. long and it is divided into 100 links. Each link having length of 1 ft.

(d) Revenue Chain – It is 33 ft. long and consists of 16 links, each link being $2\frac{1}{16}$ ft. long.

(ii) Tapes – Measurements taken by tapes are much accurate than the measurements taken by chain. Tapes can be classified into 4 types, depending upon the material used in the manufacturing of them.

(a) Cloth tape (b) Metallic tape
(c) Steel tape (d) Invar tape.

(a) Cloth Tape – These are made up of cloth. They are flexible and light in weight. They are generally 10 metre to 30 metre in length and 12 mm to 15 mm in width. The end of the tape is provided with small brass rings whose length is included in the total length of the tape. These tapes are not generally used because of the fact that, these are easily affected by moisture. They may twist during measurement. It may gets shrunk and stretched. As the cloth tapes are not accurate, they are rarely used in practice.

(b) Metallic Tape – A cloth tape reinforced with brass or copper wires is called a metallic tape. These are generally available in lengths of 10 m, 15 m, 20 m, 30 m, and 50 m. These tapes are more durable and accurate than cloth tape. These are supplied in leather cases, with a winding device.

(c) Steel Tape –The steel tapes are madeup of steel strip having width varying from 6 mm to 10 mm. These are available in lengths of 1 m, 2 m, 5 m, 10 m, 20 m, 30 m and 50 m. These tapes are more durable and accurate than the metallic tape. The end of the tape is provided with small brass rings whose length is included in the total length of the tape and which facilitate the withdrawal of the tape from the case. The case of the steel tape is madeup of leather or corrosion-resisting material. The winding device is porvided with the case for wind up the tape. Steel tapes are used for accurate measurements of distances.

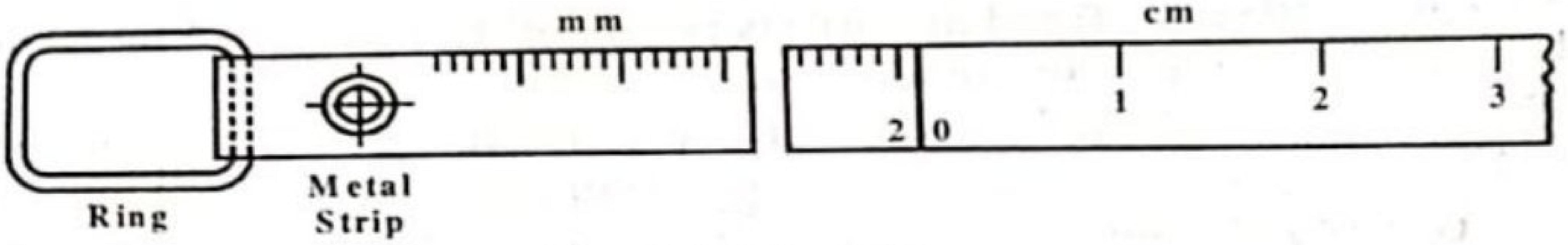


Fig. 2.5 Steel Tape

(d) Invar Tape – Invar tapes are made up of an alloy of steel (64%) and nickel (36%). Its having very low coefficient of thermal expansion of about 0.000000122 for one degree centigrade. It is 6 mm in width and it is available in lengths of 10 m, 20 m, 30 m, 50 m and 100 m. The invar alloy is a soft material, and therefore, the invar tapes should be handled carefully to avoid bends. Invar tapes are used for very accurate measurements of distance. It is used in the areas where, there is big differences in temperature.

(iii) Arrows – Arrows are used to mark the position of the ends of the chain on the ground. These are madeup of steel wire of diameter 4 mm. The length of the arrow varies between 25 cm to 50 cm but the length in common use is 400 mm. One end of the arrow is bent in the form of loop or circle and other end is pointed. Generally 10 arrows are supplied with every chain. Fig. 2.6 shows the details of an arrow.

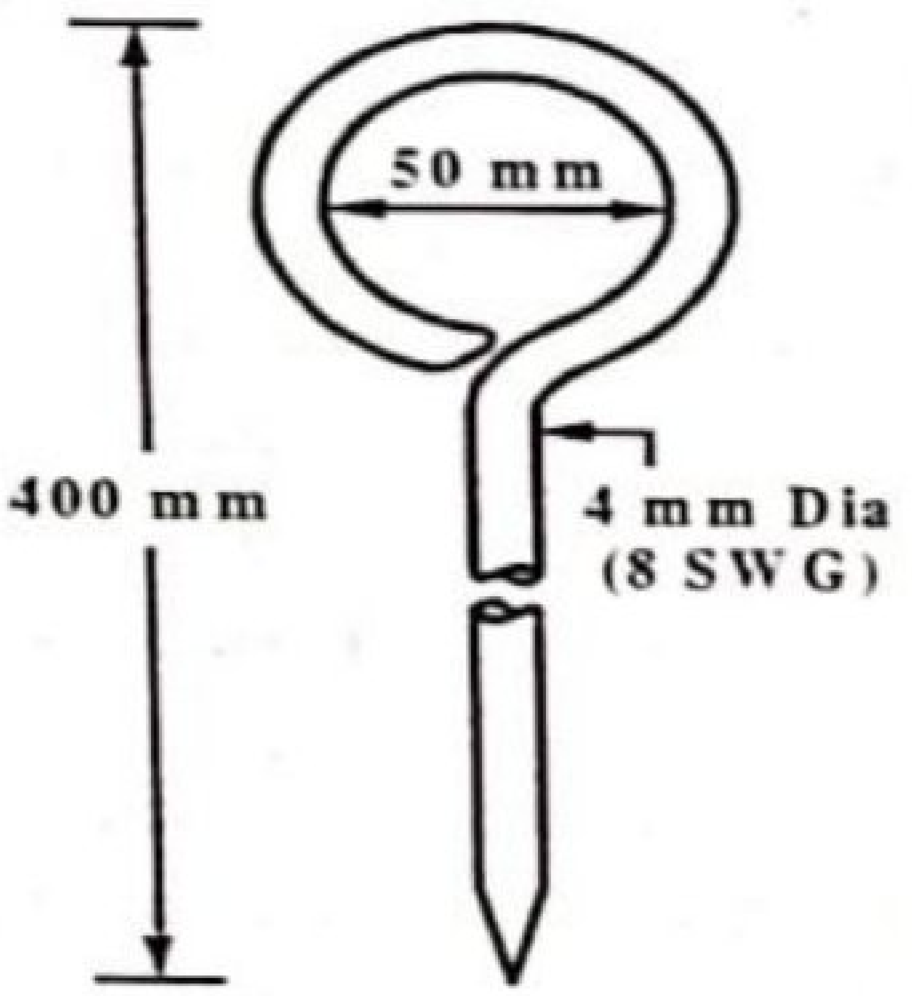


Fig. 2.6 Arrow

(iv) Pegs – These are made up of wood. These are used to mark the positions of the survey stations or the end points of a survey line. These are generally square in section, and tapered at the end. The most commonly used section are 25 mm × 25 mm in cross-section and 150 mm long. The pegs are driven in to the ground by hammer. Fig. 2.7 shows details of a peg.

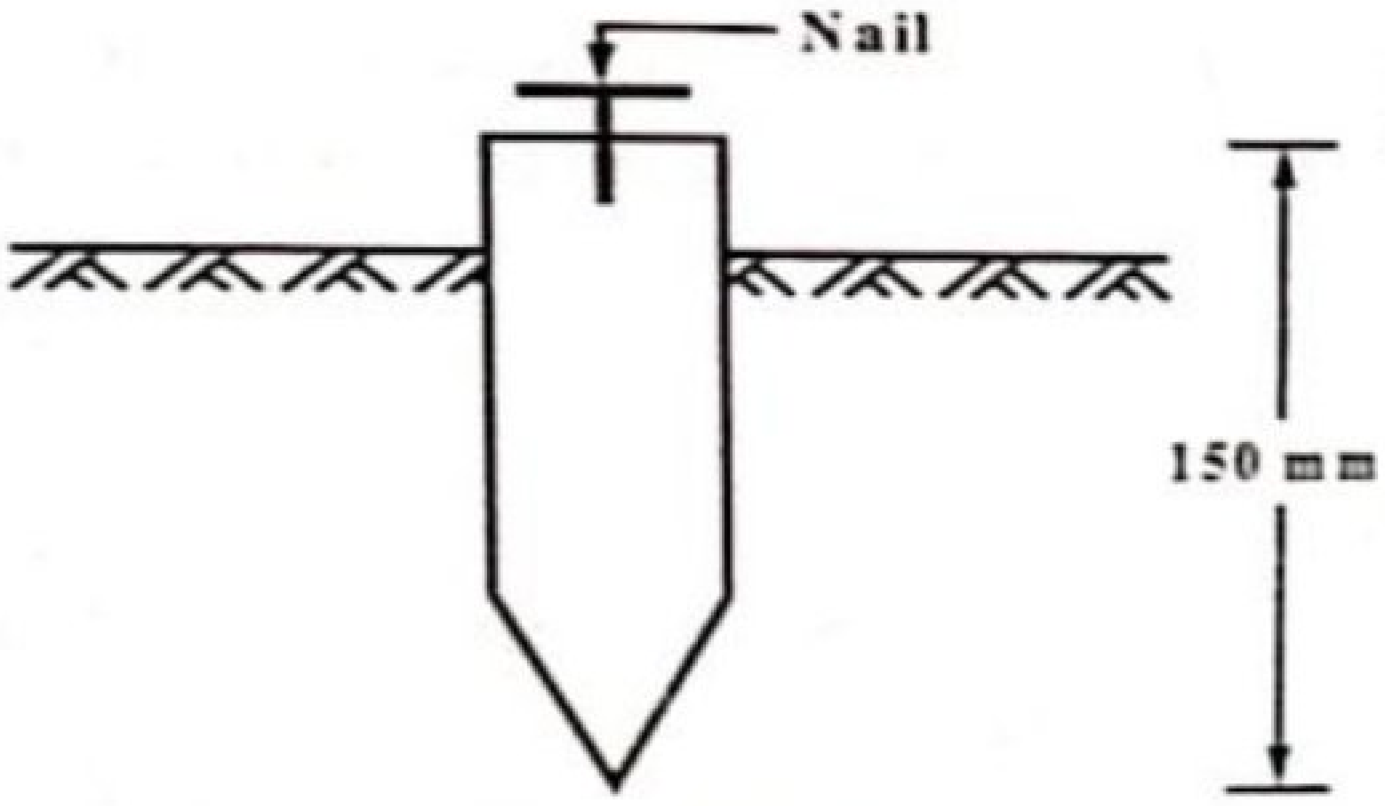


Fig. 2.7 Peg

(v) Ranging Rods – Ranging rods are used to fix up the intermediate points on a survey line. They are made up of well seasoned timber with an iron shoe at the bottom or of light steel tubes. They are generally of circular cross-section with diameter as about 3 cm. They are generally available in lengths of 2 m and 3 m. Ranging rods are painted with alternate bands of red and white or black and white. Each band being 20 cm long. Fig. 2.8 shows the details of a ranging rod.

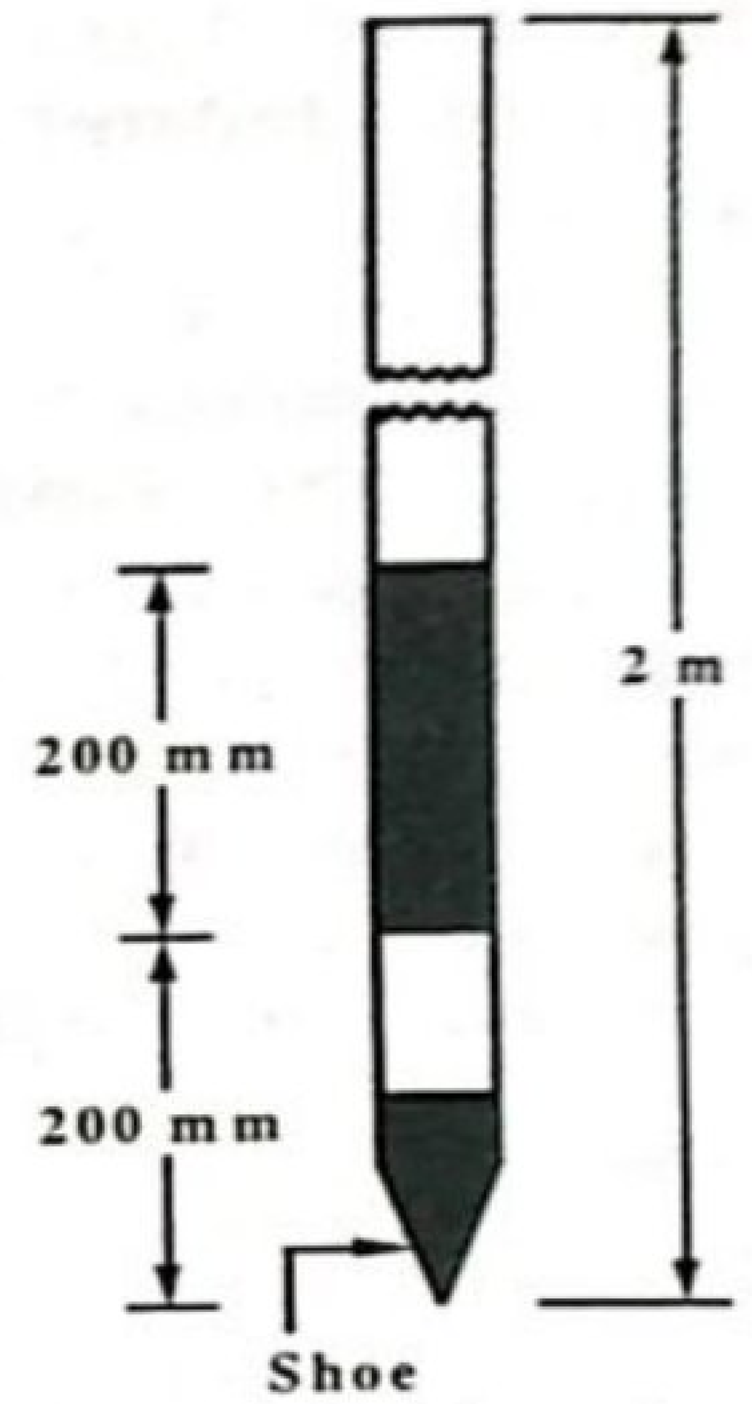


Fig. 2.8 Ranging Rod

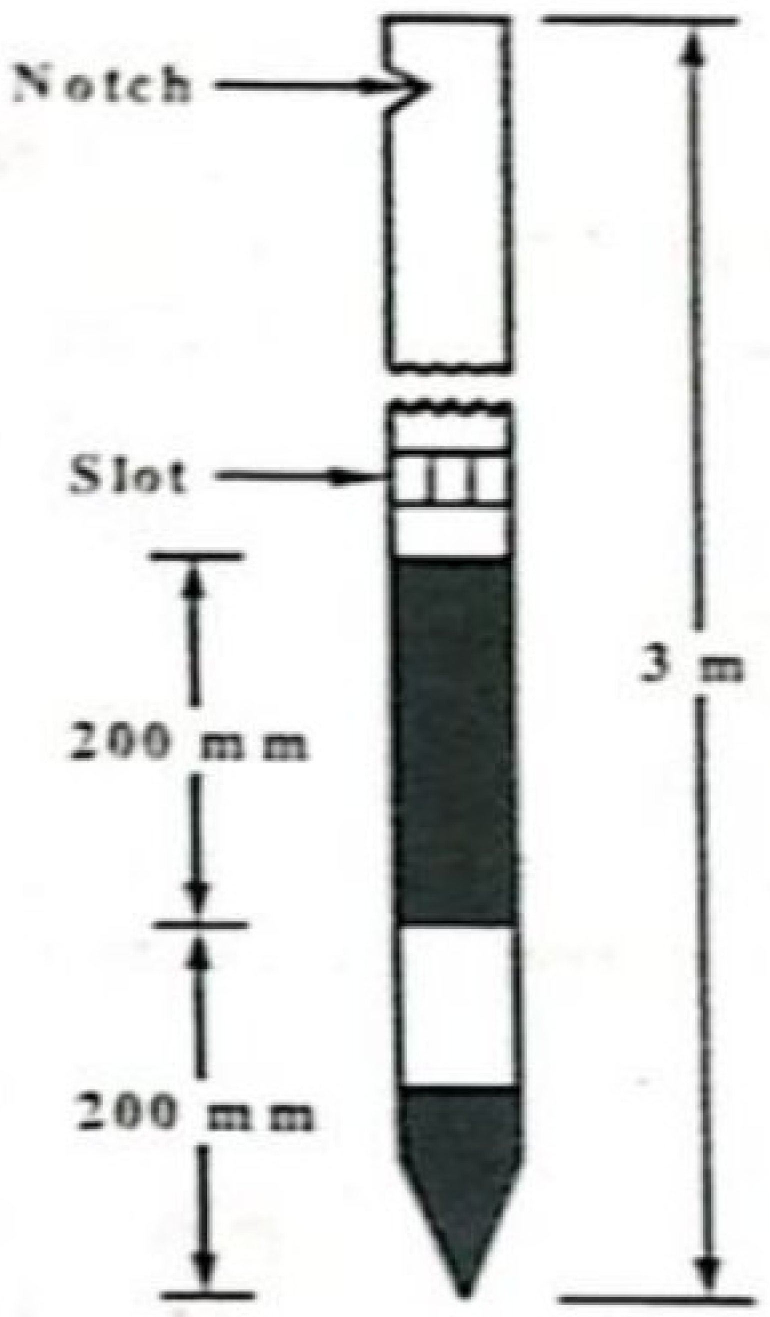


Fig. 2.9 Offset Rod

(vi) Offset Rods – Offset rods are used for setting out right angles to the survey line. The offset rod is similar to ranging rod, but has two short slots passing through the centre of the section of the rod. The slots are madeup at right angles to each other at about the eye level of the person. The length of offset rod is usually 3 m. There is a notch at the one end of the offset rod and other end has a pointed iron shoe. Fig. 2.9 shows the details of the offset rod.

(vii) Plumb Bob – A plumb bob consists of a string attached at the top of the metal bob. As freely suspended plumb bob always points towards the gravity it indicate the direction of the vertical line. Plumb bob is required to transfer the points on ground while chaining along sloping ground. The verticality of surveying instruments such as dumpy level, theodolite, compass and ranging rod, can be tested by suspending a plumb along them. It is also used for centering of surveying instruments. Fig. 2.10 shows the details of the plumb bob.

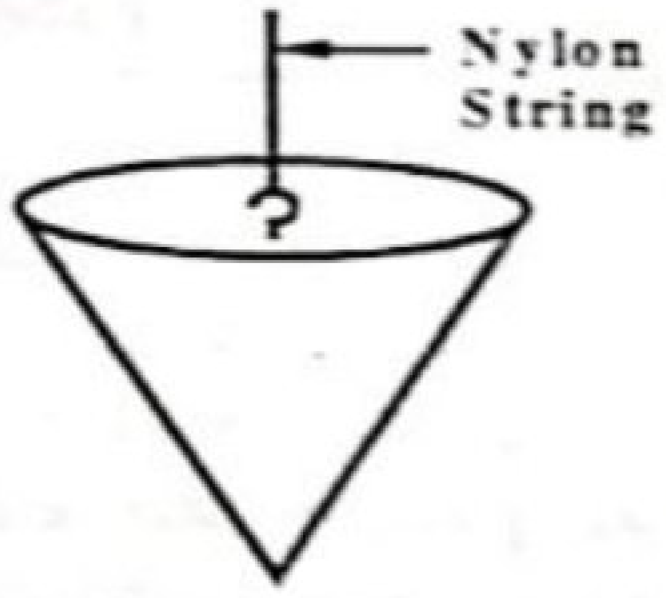


Fig. 2.10 Plumb Bob

Q.7. What do you understand by term ranging ? Explain different types of ranging. ***(R.G.P.V., June 2003, 2005, Feb. 2005)***

Ans. The process of fixing intermediate points during chaining to maintain the direction of the work is known as ranging. For the measurement of survey line, it is essential to stretch the chain or tape. If the distance is less than the chain length, then chain can be stretched directly, but if distance is more than the chain length, then it is necessary to establish intermediate points or if there is some obstruction between two points and the visibility is affected in such cases the ranging will be required.

Types of Ranging – There are two types of ranging –

(i) Direct ranging (ii) Indirect ranging.

(i) Direct Ranging – In this method, intermediate points are fixed by direct measurements only. This type of ranging is possible when two stations are intervisible. Direct ranging is carried out by following instruments –

(a) Ranging by eye (b) Ranging by line ranger.

(a) Ranging by Eye – In this method, the surveyor stands at a distance of about 150 cm beyond station A. Assistant surveyor stands up between stations A and B. Now surveyor will directs assistant surveyor by some code signals of hand movement. Whenever intermediate rod is in straight line of stations A and B, he gives signal to fix up the intermediate rod. Table 2.1 shows the code singnals of hand movement.

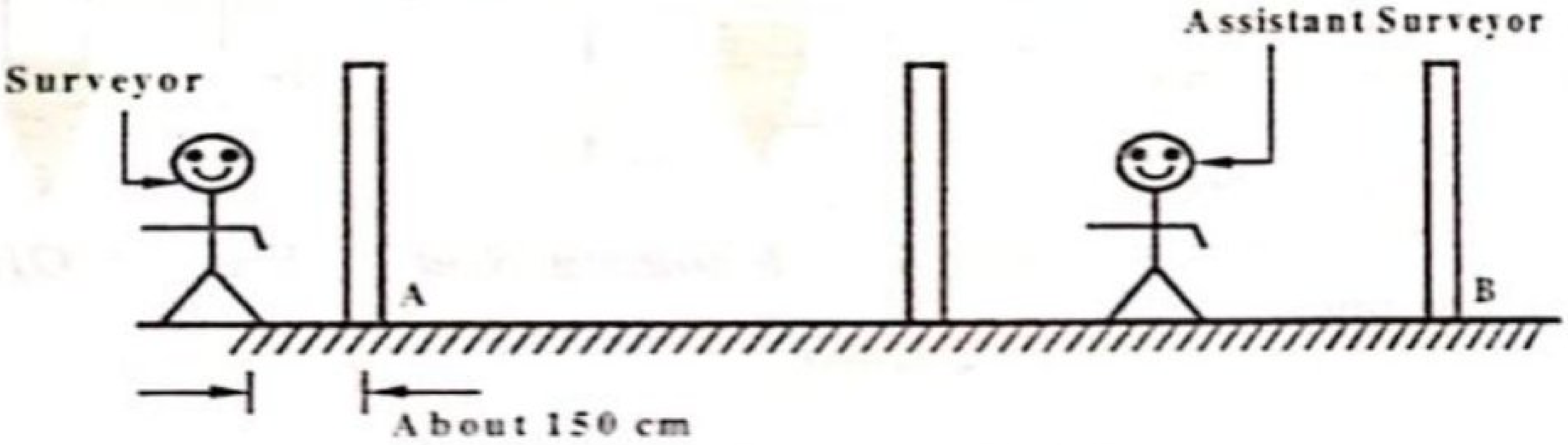


Fig. 2.11 Ranging by Eye

Table 2.1 Code Signals of Hand Movement

S.No.	*Code*	*Meaning*
(i)	Rapid sweep of right hand [Fig. 2.12 (a)].	Move considerably to your left.
(ii)	Slow sweep of right hand.	Move slowly to your left.
(iii)	Right arm extended [Fig. 2.12 (b)].	Continue to move to your left.
(iv)	Right arm up and moved to the right [Fig. 2.12 (c)].	Move the ranging rod to your left from the top.
(v)	Rapid sweep of left hand [Fig. 2.12 (d)].	Move considerably to your right.
(vi)	Slow sweep of left hand	Move slowly to your right.
(vii)	Left arm extended [Fig. 2.12 (e)].	Continue to move your to right.
(viii)	Left arm up and moved to the left [Fig. 2.12 (f)].	Move the ranging rod to your right from the top.
(ix)	Both hands above head and then brought down.[Fig. 2.12 (g)].	Ranging is correct.
(x)	Both arm extended forward horizontally and then brought down quickly.	Fix the ranging rod.

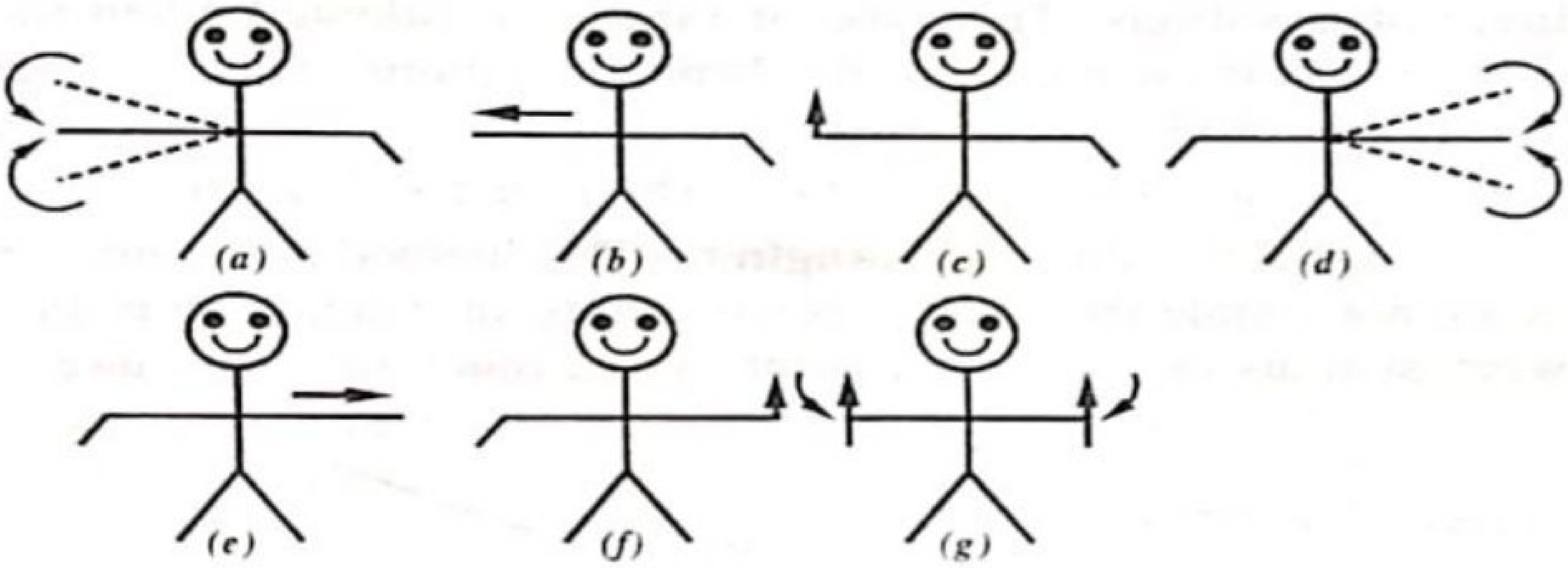


Fig. 2.12 Code Signals of Hand Movement

(b) Ranging by Line Ranger – Line ranger consists of two right angled isosceles triangular prisms placed one above the other. The diagonals of both prisms are silvered so as to form the reflecting surfaces. A handle is provided at the bottom of the instrument to hold the instrument. A hook is provided at the bottom of the instrument for holding plumb bob. This instrument works on the principle of prismatic reflection. Line ranger avoids the assistant, who takes the intermediate ranging rod, that means it requires only one person for the purpose of ranging. Line ranger is used for accurate and speedy work.

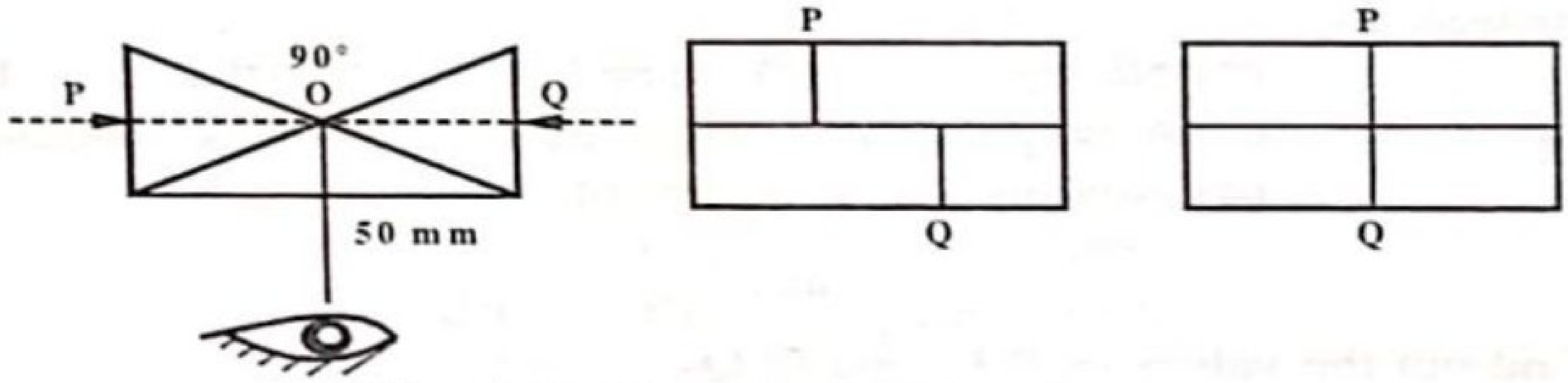


Fig. 2.13 Ranging by Line Ranger

The following procedure is used to establish a point on the line PQ with a line ranger –

(1) Firstly hold the instrument very near to the line PQ.

(2) Observe ranging rod at 'P' through prism KLM.

(3) Observe ranging rod at 'Q' through prism PLM.

(4) Move towards line PQ until both images appear exactly one above the other.

(5) The required intermediate station 'O' is exactly below the inter-section of the two diagonal.

(ii) Indirect Ranging (Or Range a Chain between Two Points Which are not Visible) – In this case, intermediate points are find out by interpolation of indirect observations. This type of ranging is adopted when the vision between two stations is not clear or when two stations are not visible. There are two methods of indirect ranging –

(a) Random line ranging (b) Reciprocal ranging.

(a) Random Line Ranging – This method is adopted when end stations are not visible from intermediate points, or when there is an obstacle in between stations or when both points are at much more distance.

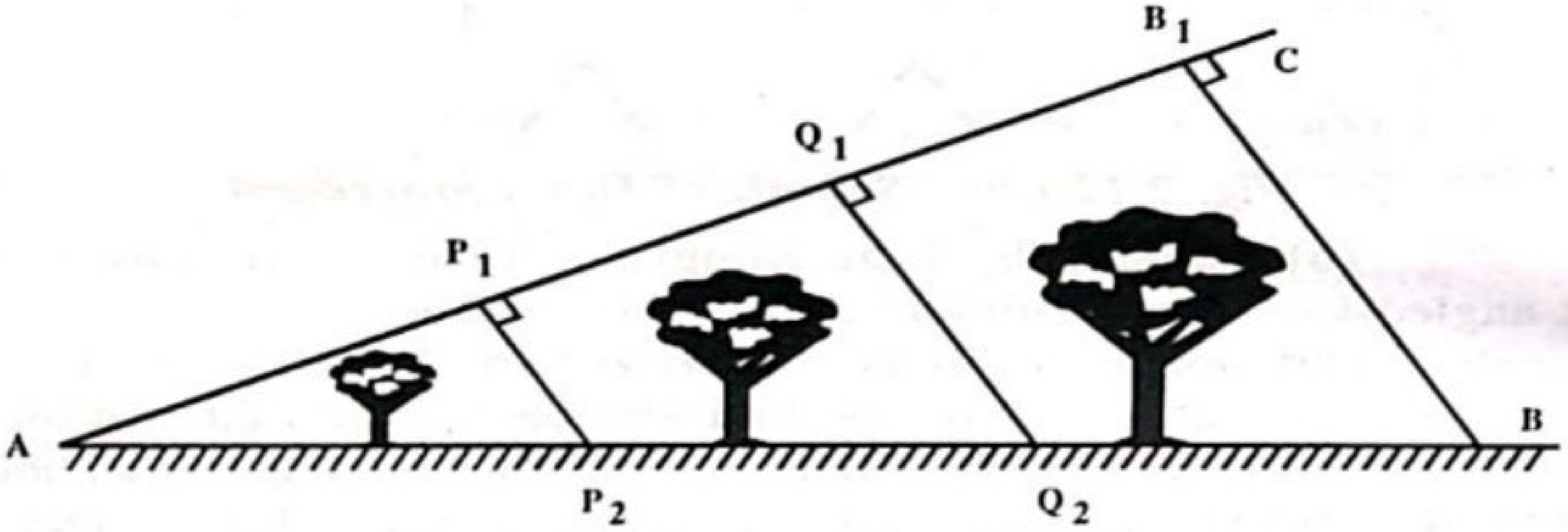


Fig. 2.14 Random Line Ranging

The procedure of random line ranging is as follows –

(1) Random line AC is drawn, which should be clearing the obstruction, from station A.

(2) Now point B_1 is fixed on line AC, such that $\angle AB_1B = 90^\circ$

(3) Now points P_1 and Q_1 are fixed by direct ranging.

(4) Now by the properties of similar triangle,

$$\frac{AP_1}{AB_1} = \frac{P_1P_2}{BB_1} \text{ and } \frac{AQ_1}{AB_1} = \frac{Q_1Q_2}{BB_1}$$

and find out the values of P_1P_2 and Q_1Q_2.

(5) Now perpendiculars P_1P_2 and Q_1Q_2 are drawn at the points P_1 and Q_1.

(6) P_2 and Q_2 will cut the line AB at such intermediate points, those we have required.

(b) Reciprocal Ranging – This type of ranging is adopted when two points 'A' and 'B' are not intervisible due to some obstruction such as hill. The following procedure is usually adopted –

(1) Two ranging rods are fixed at points A and B.

(2) Now two persons moves on the hill and reached to the positions C_1 and D_1 in such a manner so that the person at C_1 can see the ranging rods at D_1 and B and similarly, the person at D_1 can see the ranging rods at C_1 and A.

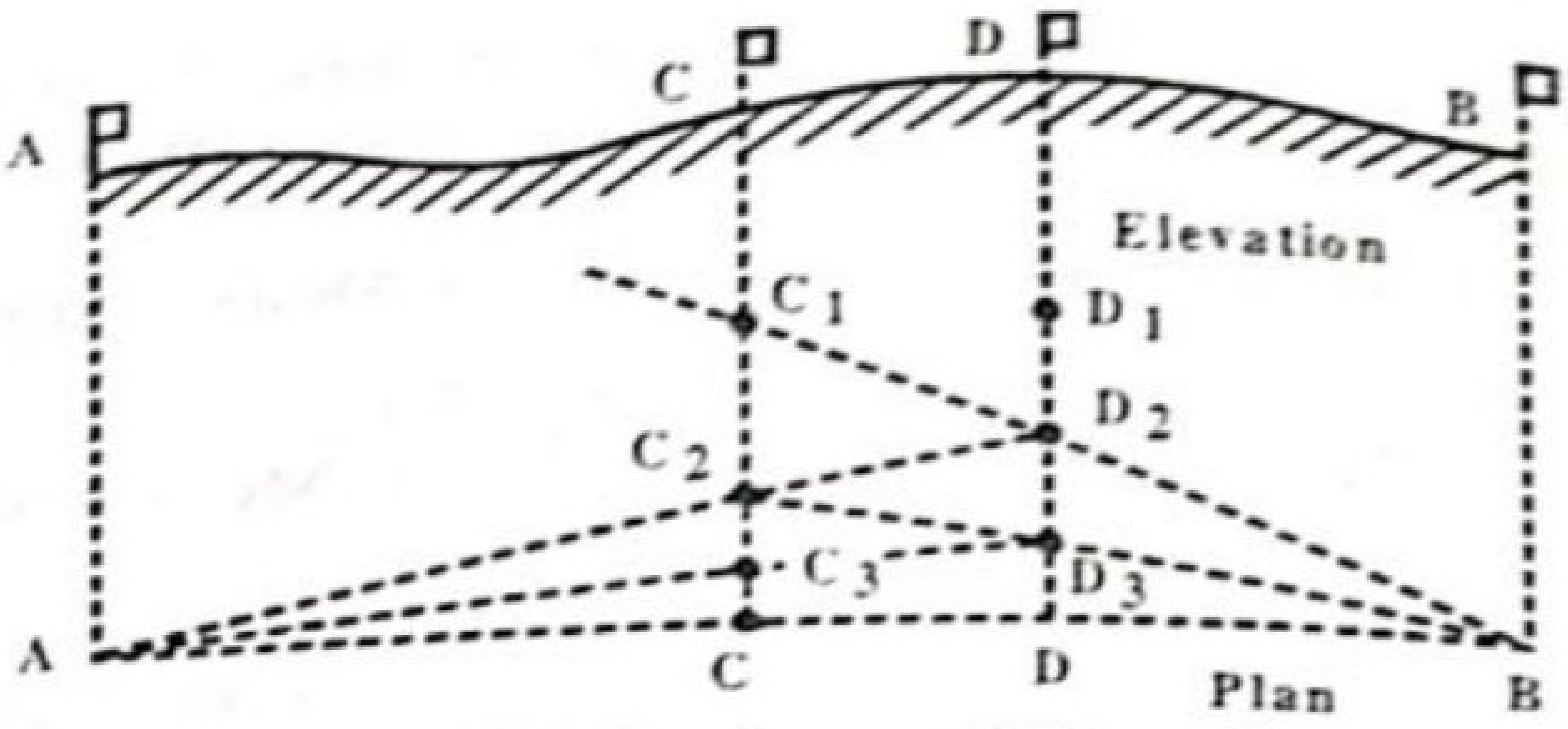


Fig. 2.15 Reciprocal Ranging

(3) Now person who is standing at position C_1 will direct the person who is standing at D_1 in such a way so that he will takes up the position D_2 in line with C_1B.

(4) Now person who is standing at position D_2 will direct the person who is standing at C_1 in such a manner so that he will takes up the position C_2 in line with D_2A.

(5) Procedure is repeated until the intermediate stations C and D are established.

Q.8. Write a brief note on – Chaining on plain ground.

Ans. Number of person required for the purpose of chaining are four. One leader, one follower, and two assistants. The person at the forward end is called leader. The person at the rear end is called follower.

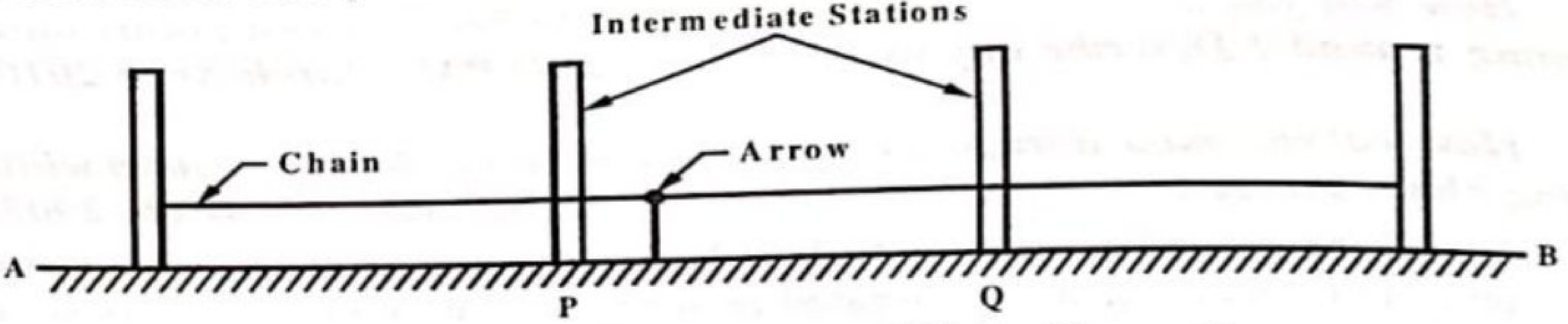


Fig. 2.16 Chaining on Plain Ground

The procedure of chaining is as follows –

(i) Firstly two stations A and B are fixed. After that two intermediate points P and Q are fixed by ranging.

(ii) The leader will take up the chain and will moves towards P from A. Leader gets instructions from the follower and stands in line with AP.

(iii) At the end of the chain, leader will fix up the arrow.

(iv) The leader will now tooks up the chain and will moves towards Q. The follower will move in the direction AP.

(v) Whenever follower will reached near the arrow he will stop. So the leader will stops moving further.

(vi) The procedure is repeated until point B is reached.

Q.9. How will you applied the chain corrections if measurements are done with wrong chain ?

Ans. Before starting the chaining, the chain should be tested and adjusted.

If it is noticed that the measurements were taken by a wrong chain, the corrections should be applied in the following manner –

$$\text{True length of line} = \frac{L_1}{L} \times \text{Measured length of the line}$$

$$\text{True area of land} = \left(\frac{L_1}{L}\right)^2 \times \text{Measured area}$$

$$\text{True volume} = \left(\frac{L_1}{L}\right)^3 \times \text{Measured volume}$$

where, L = True length of the chain
L_1 = Incorrect length of the chain
$= L + e$, if chain is long
$= L - e$, if chain is short
e = Elongation or shortening of the chain.

Q.10. Explain the different methods of chaining on sloping ground. ***(R.G.P.V., Dec. 2005)***

Or

How will you measure a horizontal distance between two points on a sloping ground ? Describe any two methods. (R.G.P.V., March/April 2010)

Or

How will you make horizontal measurements on a sloping ground while doing chain survey ? ***(R.G.P.V., Jan./Feb. 2007)***

Ans. If the ground slope is up to 1 in 20, it is treated as plain ground. But if slope is more than 1 in 20, it is treated as sloping ground. For the purpose of plotting, the corresponding horizontal distances of sloping ground are required. There are basically two methods –

(i) Direct method (ii) Indirect method.

(i) Direct Method – In this method, the horizontal distances are measured directly by stepping. Suppose there are two points A and B on the sloping ground and we have to determine the equivalent horizontal distance AB. The procedure will be as follows –

(a) Two persons namely leader and follower are required for this process. Leader holds the one end of the chain and moves towards the point B and reached to point a_1.

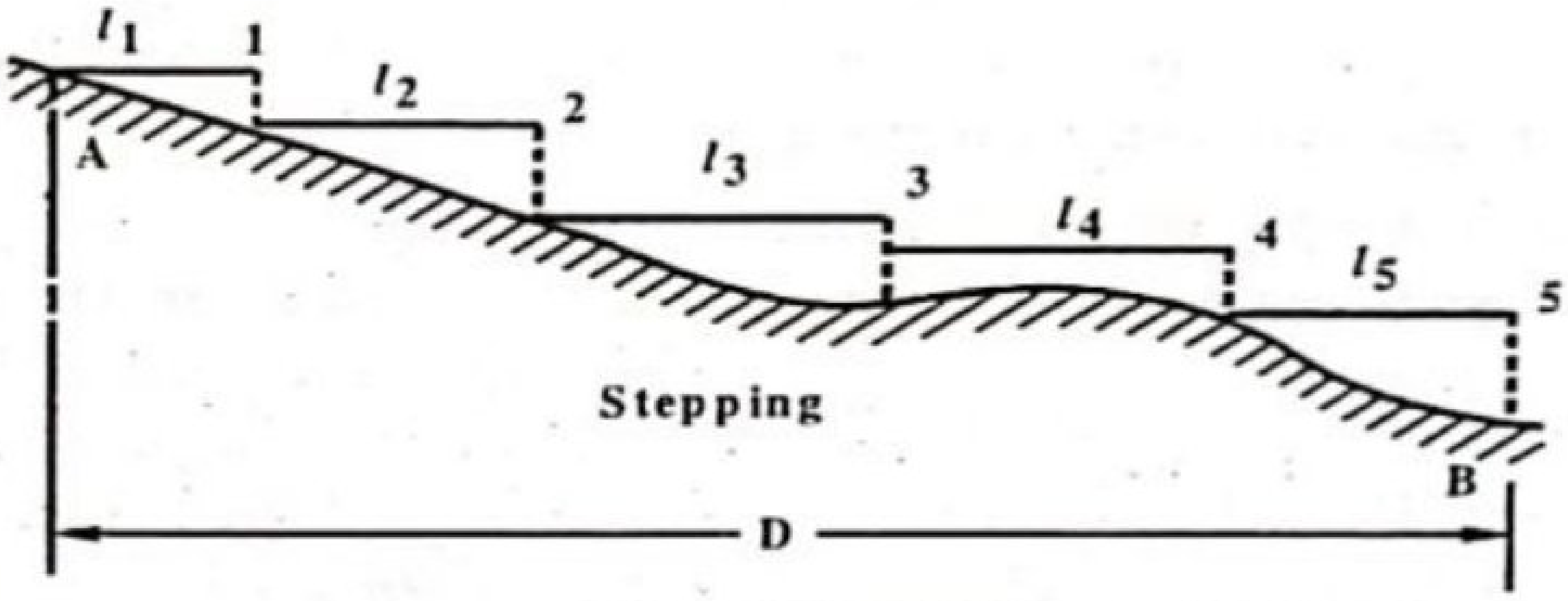
(b) Now leader will stretched the chain in such a way so that it is more or less horizontal.

(c) Now follower at A will ranges the leader in line AB.

(d) After correct ranging, the leader will transfer the point a_1 to the point a_2 which is on the ground, with the help of plumb bob, fix up an arrow at that point a_2.

(e) After that leader will moves forward and follower will reach to the point a_2 and the process is continue till point B is reached.

(f) The horizontal distance AB = $l_1 + l_2 + l_3 + l_4 + l_5$



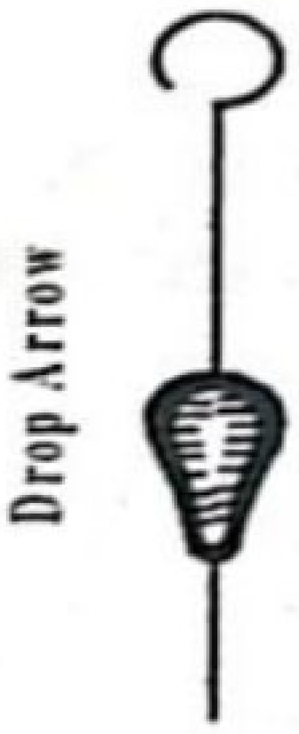


Fig. 2.17 Direct Method

(ii) Indirect Method – In this method, the inclined distance is measured along the slope. Then by geometrical considerations, it is converted in to equivalent horizontal distance. There are usually three methods those are used to determine the equivalent horizontal distance from inclined distance.

(a) Hypotenusal allowance

(b) Measuring angle of inclination

(c) Measuring difference in level.

(a) Hypotenusal Allowance – If L is the length of the chain and θ is the angle of slope of the ground.

For finding out horizontal distance L = chain length. It is required to measure the distance L sec θ on sloping ground. So that amount L (sec θ –1) should be added to every chain length, to finding out distance L sec θ on sloping ground. This distance L (sec θ –1) is known as hypotenusal allowance.

The slope angle θ is measured with the help of an instrument clinometer. Clinometer consists of the following three parts –

(i) Graduated semicircle with protractor

(ii) Plumb bob

(iii) Line of sight.

Whenever, instrument is horizontal, the thread which is suspended on the clinometer touches the zero mark of the graduated arc. For determining the slope angle θ, firstly, mark is made

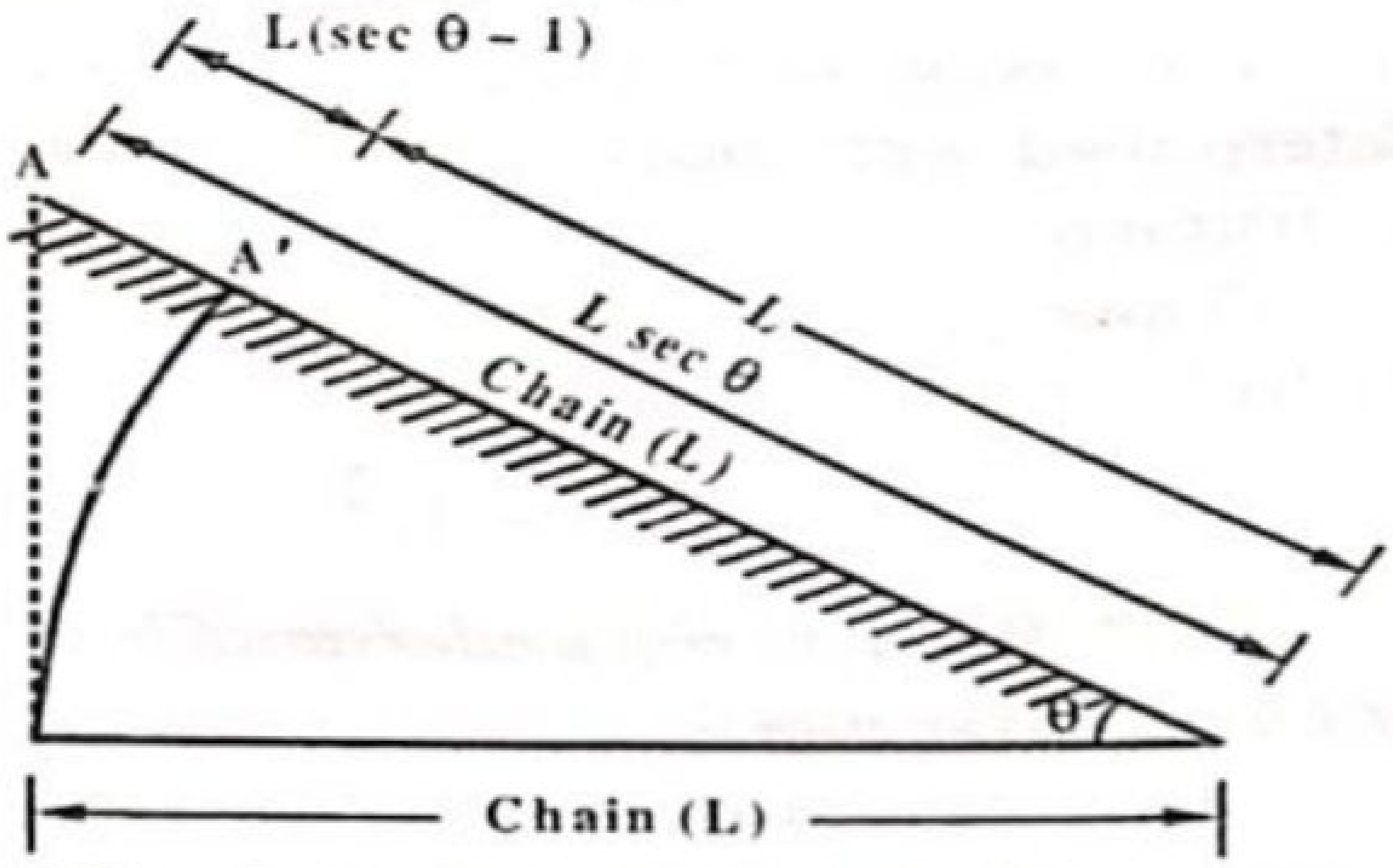


Fig. 2.18 Hypotenusal Allowance

on the ranging rod at the height of the observer's eye. The leader will kept that ranging rod and will reached to the point B. Whereas, the follower will stand at A with the clinometer in his hand. Follower, then sights through the clinometer to the mark made on ranging rod at B. The thread will remain vertical and plumb bob will be on the station. The angle of slope is read on the graduated semi circle against the thread.

(b) Measuring Angle of Inclination– In this method, the slope angle θ, is determined with the help of an instrument clinometer. In figure, angles, θ_1,θ_2, θ_3, θ_4 are measured with the help of an instrument clinometer. Distances l_1, l_2, l_3, l_4 are measured along the slope with the help of the chain or tape. If l_1, l_2, l_3, l_4 are the inclined distance, measured along the slope form A to B, then the horizontal distance D is given by following equation.

Horizontal distance $D = l_1\cos\theta_1 + l_2\cos\theta_2 + l_3\cos\theta_3 + \ldots\ldots\ldots$

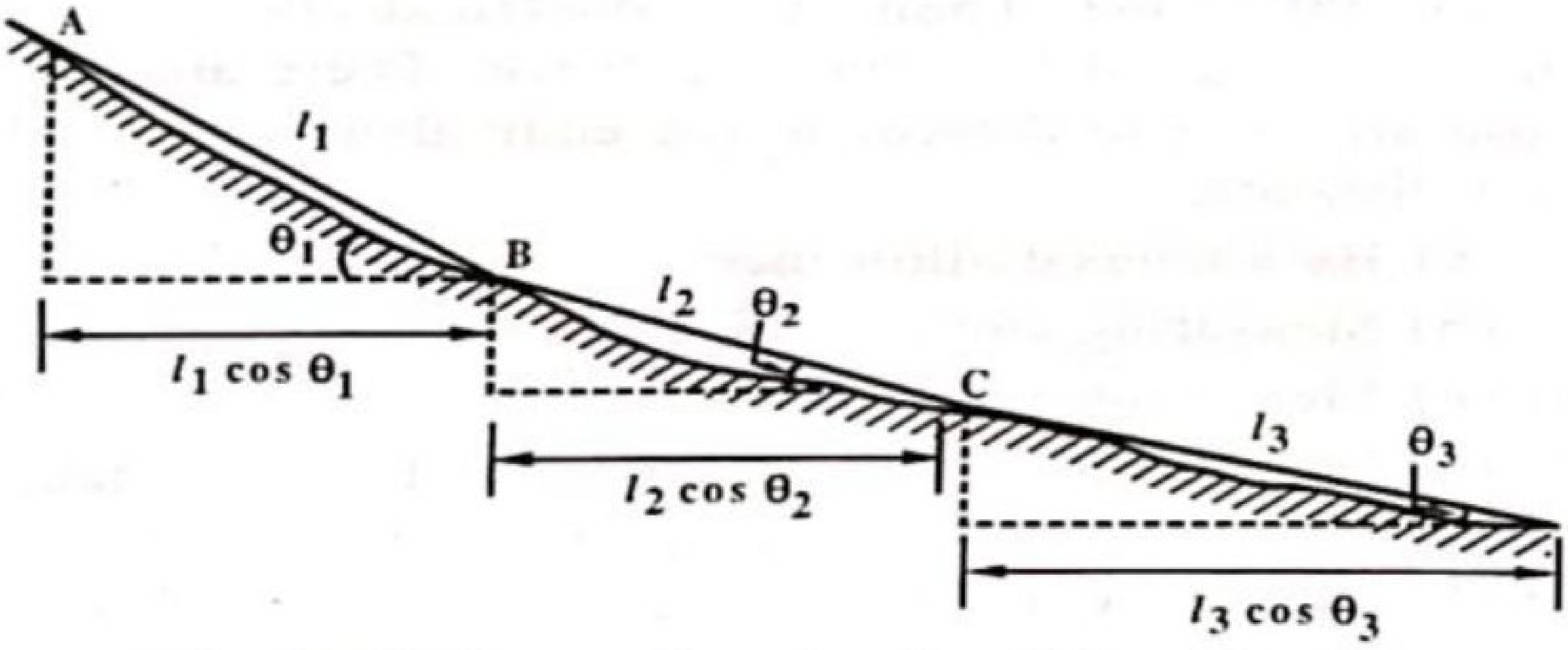


Fig. 2.19 Measuring Angle of Inclination

(c) Measuring Difference in Level – In this method, inclined distance L, measured along the slope with the help of chaining. The difference in elevation between two points A and B is determined with the help of an levelling instrument.

Then horizontal distance D is given by following equation,

$$D = \sqrt{L^2 - H^2}$$

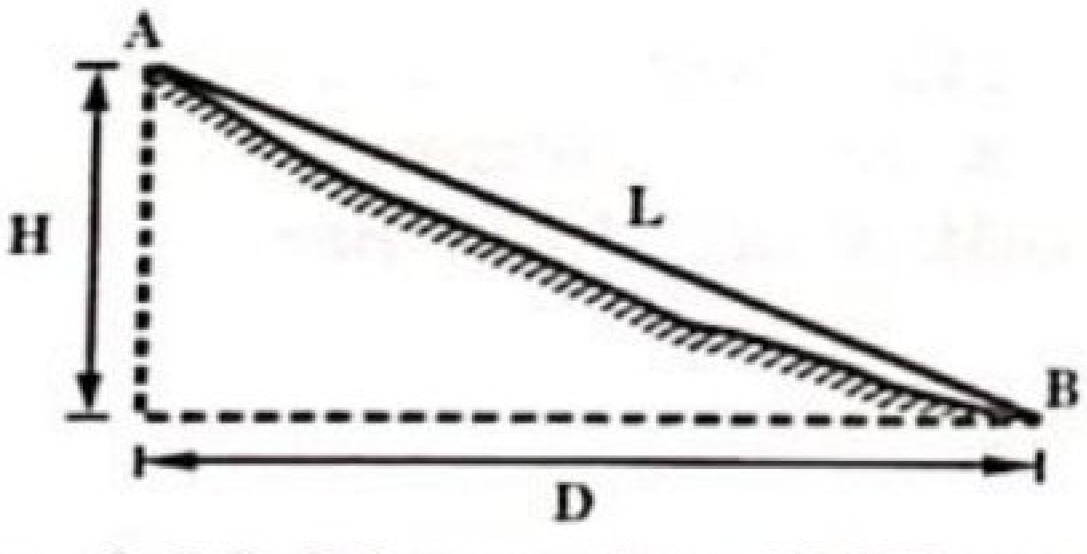


Fig. 2.20 Measuring Difference in Level

Q.11. What do you understand by chain surveying ? What is the principle of chain surveying ?

Ans. Chain surveying is one of the method of land surveying. It is the type of the surveying in which only linear measurements are made, no angular measurements are taken. It is the simplest and accurate method of land surveying. In this, linear distances are measured on the field.

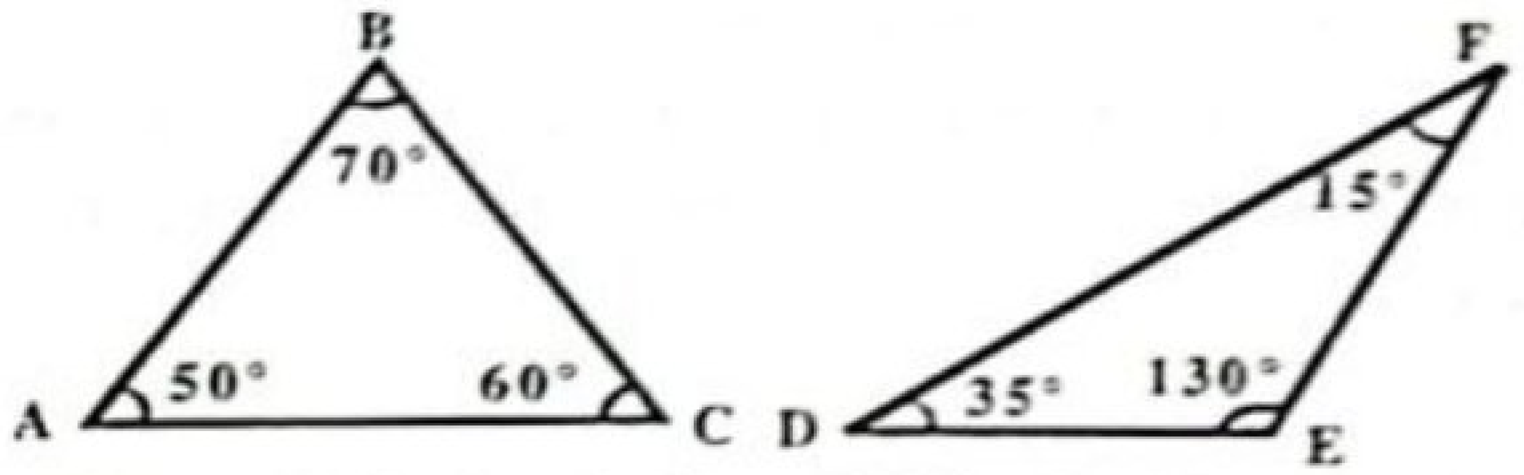


Fig. 2.21 Principle of Chain Surveying

The principle of chain surveying is to divide the whole area into number of triangles of suitable sides. Great care has to be taken in the formation of triangles so that the process of chain surveying becomes smooth. As far as possible, the triangles formed should resemble to the shape of an equilateral triangle. The triangles formed should be well conditioned triangle. The triangles which are very nearly equilateral are known as well conditioned triangles. A well conditioned triangle should not contain no angle greater than 120° and less than 30°.

Q.12. List out of various surveying instruments. Also show their application. ***(R.G.P.V., Dec. 2015)***

Ans. Following instruments are required for carrying out the chain surveying –

(i) Chain – For measuring linear measurements.

(ii) Arrows (10 Nos) – Used after end of every chain length.

(iii) Ranging Rods (10-15 Nos) – To fix up intermediate points on main chain line.

(iv) Offset Rod – To maintain direction of offset line.

(v) Cross Staff – To set right angles or perpendicular offsets.

(vi) Plumb Bob – For centring of surveying instruments.

(vii) Field Book – To notedown the field observations.

(viii) Miscellaneous items like pencil, rubber, knife, hammer, axe, nails, pegs, chalk, bundle of strings etc.

Q.13. What is survey station ? Where this term use ? ***(R.G.P.V., June 2016)***

Or

Describe the survey stations. ***(R.G.P.V., April 2009, June 2010)***

Or

Define survey station. ***(R.G.P.V., June 2015)***

Or

Explain survey station and its importance. ***(R.G.P.V., Dec. 2016)***

Ans. Beginning or end point of the survey line is called as survey station. There are two types of stations –

(i) Main station (ii) Subsidiary or tie station.

(i) Main Station – Stations taken along the boundary of an area are known as main stations, or main survey stations are the points which are connected by survey lines to form the triangles.

(ii) Subsidiary of Tie Station – The points which are selected on the main survey lines, for running tie lines are called as subsidiary or tie stations.

This term is used in surveying for different types of fields and lands. The term survey station denotes the particular station in the field/land given by the surveyor during survey.

Q.14. What are survey stations ? How are they selected ?
(R.G.P.V., Dec. 2006)

Ans. **Survey Stations** – Refer Q.13.

For Selection – The following points should be kept in mind while selecting survey stations –

(i) Main survey stations at the ends of chain lines should be intervisible.

(ii) Survey lines should be minimum possible.

(iii) The main principle of surveying viz. working from the whole to the part and not from the part to the whole should be strictly observed.

(iv) Base line should be run roughly through the centre of the area. It should be laid on level ground.

(v) Survey stations should form well conditioned triangles.

(vi) Every triangle should be provided with a check line.

(vii) Tie lines should be provided to avoid too long offsets.

(viii) Obstacles to ranging and chaining should be avoided.

(ix) The larger side of the triangle should be placed parallel to the boundaries, roads, buildings etc. to have short offsets.

(x) To avoid trespassing, the main survey lines should remain within the boundaries of the property to be surveyed.

(xi) Chain lines should lie preferably over level ground.

(xii) Lines should be laid on one side of the road to avoid interruption of chaining by passing traffic.

Q.15. Describe the survey lines. ***(R.G.P.V., June 2010)***

Ans. The lines joining the survey stations are called as survey lines. These are of following types –

(i) Base lines (ii) Main survey lines (iii) Tie lines (iv) Check lines.

(i) Base Lines – Longest line of the main survey lines is called as base line. This base line is firstly plotted on the paper. In actual, this is the line on which frame work of the survey is built.

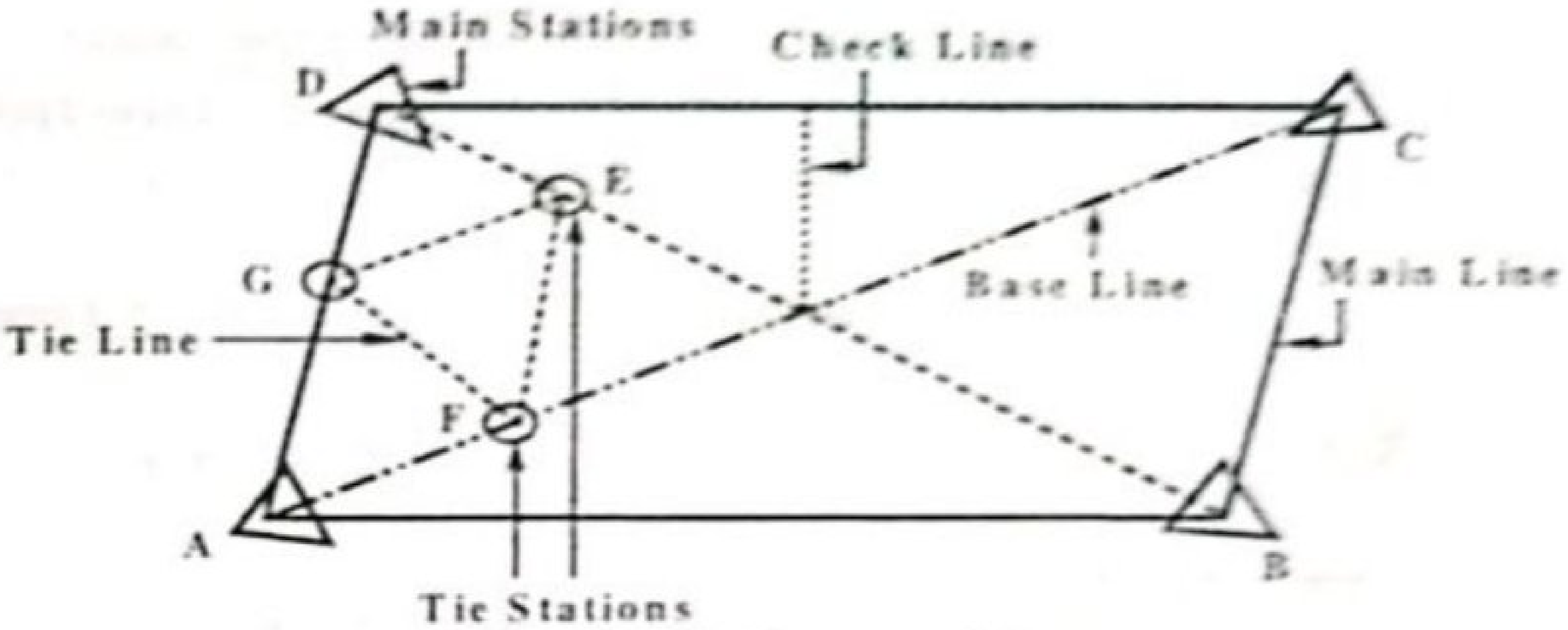


Fig. 2.22 Survey Lines

(ii) Main Survey Line – Line joining the main survey stations is called as main survey line.

(iii) Tie Lines – The chain line which connects the subsidiary or tie stations is called as tie line.

(iv) Check Lines – It is the line which run in the field to check the accuracy of the work. The length of the check line measured in the field must agree with its length on the plan.

Q.16. What are offsets in chain surveying ? How are they taken in the field ? ***(R.G.P.V. June 2002, 2005)***

Ans. Offsets are the lateral distances measured from the survey lines, to locate the position of a point with respect to the survey line. The offsets are of two types –

(i) Perpendicular offsets (ii) Oblique offsets.

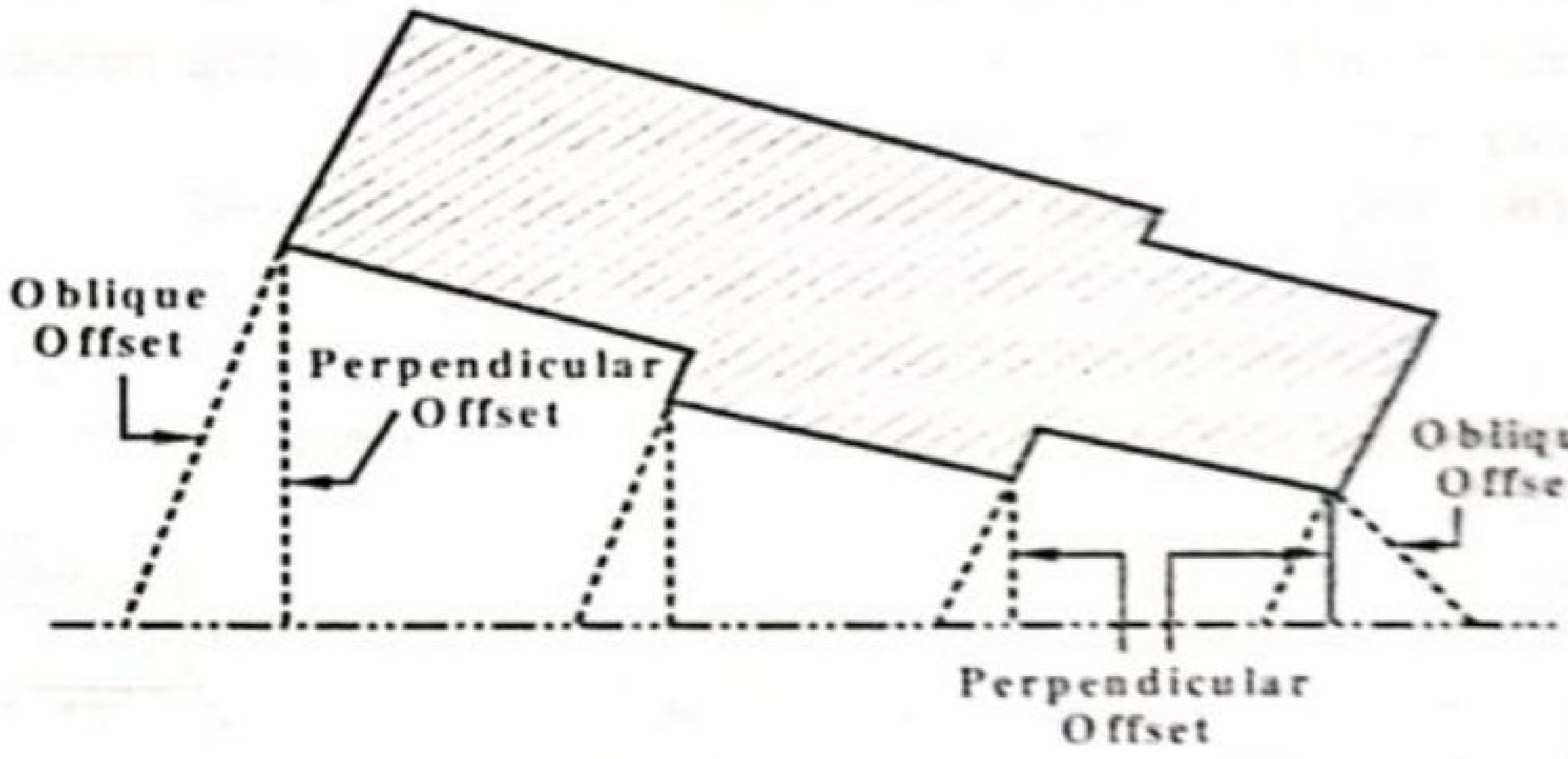


Fig. 2.23 Offsets

(i) Perpendicular Offsets – When the lateral measurements are taken perpendicular to the chain line, they are known as perpendicular offsets (see fig. 2.24).

Perpendicular offsets may be taken in the following ways –

(a) By setting a perpendicular by swinging a tape from the objec to the chain line. The point of minimum reading on the tape will be the base of the perpendicular (see fig. 2.25).

(b) By setting a right angle in the ratio 3 : 4 : 5 (see fig. 2.26).

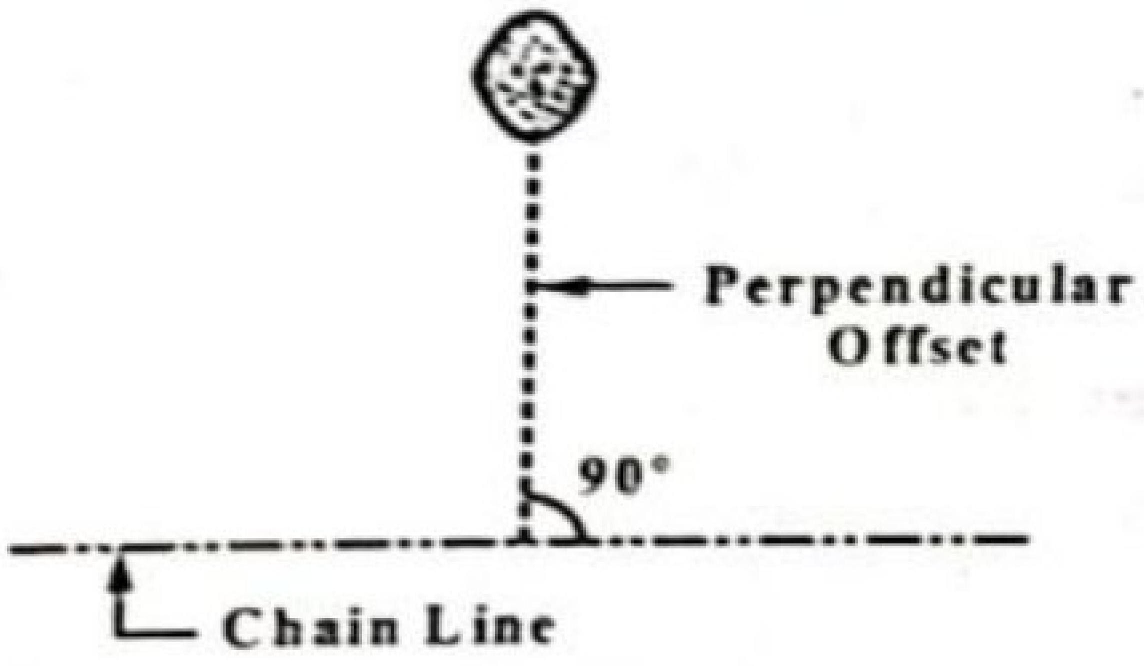


Fig. 2.24

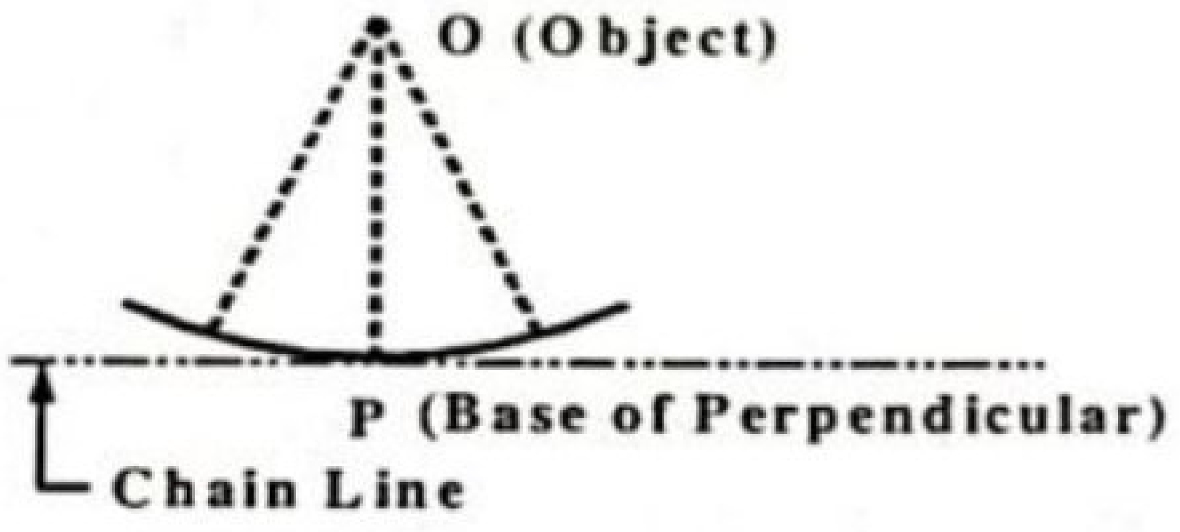


Fig. 2.25

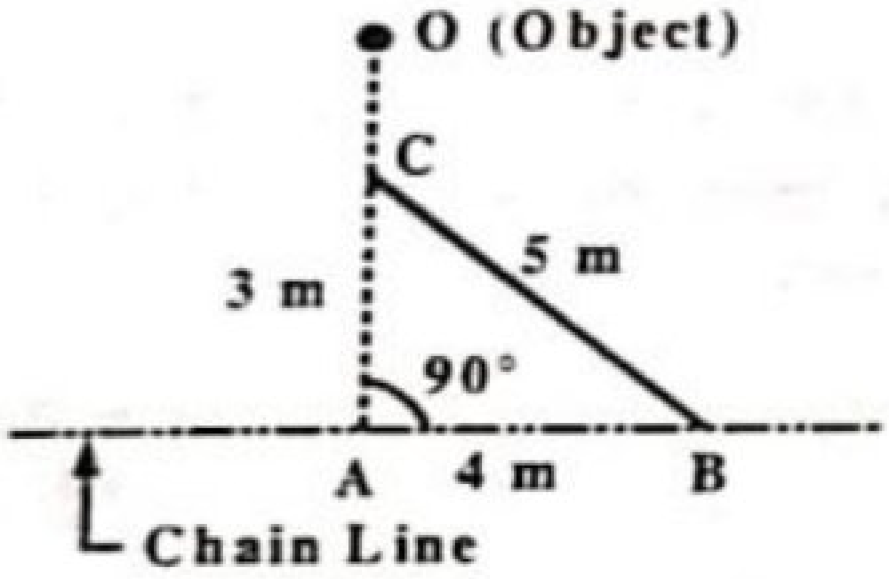


Fig. 2.26

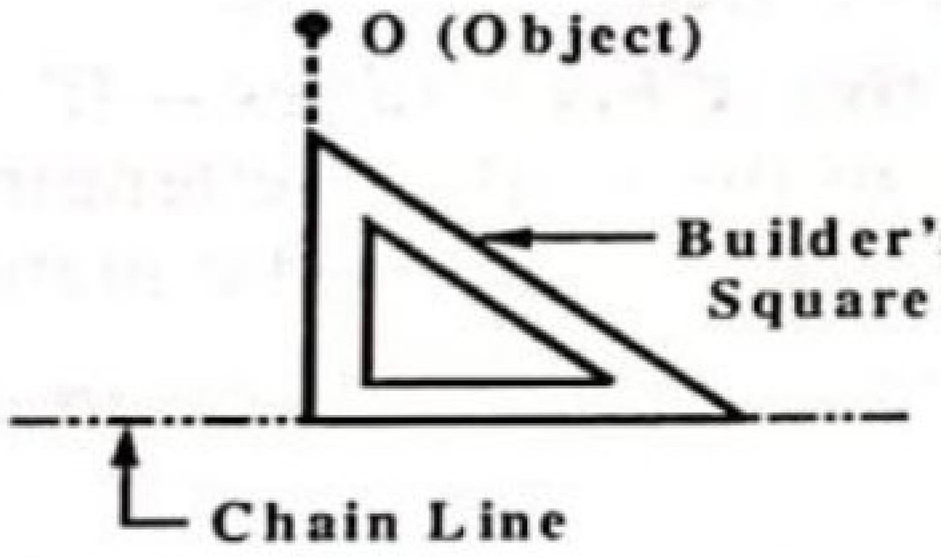


Fig. 2.27

(c) By setting a right angle with the help of builder's square or tri-square (see fig. 2.27).

(d) By setting a right angle by cross-staff or optical square.

Perpendicular offsets are preferred for the following reasons –

(a) They can be taken very quickly.

(b) The progress of survey is not hampered.

(c) The entry in the field book becomes easy.

(d) The plotting of the offsets also becomes easy.

(ii) Oblique Offsets – Any offset not perpendicular to the chain line is said to be oblique. Oblique offsets are taken when the objects are at a long distance from the chain line or when it is not possible to set up a right angle due to some difficulties. Such offsets are taken in the following manner.

Suppose AB is a chain line and P is the corner of a building. Two points 'a' and 'b' are taken on the chain line. The chainages

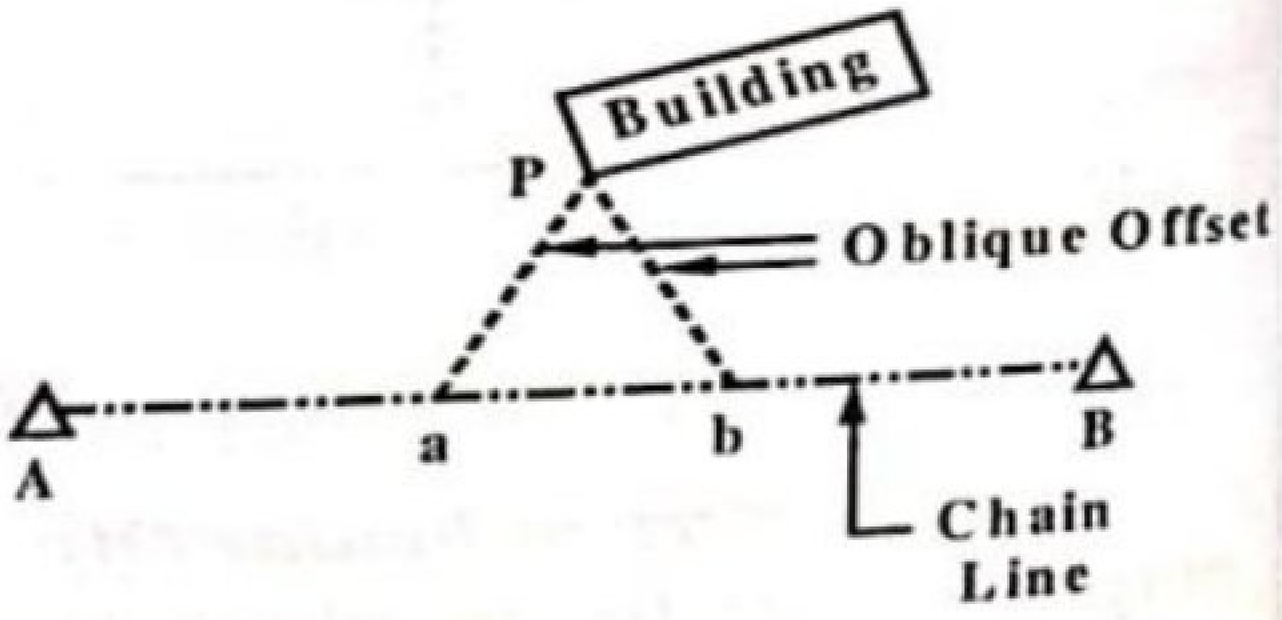


Fig. 2.28

of 'a' and 'b' are noted. The distances 'aP' and 'bP' are measured and noted in the field book. Then 'aP' and 'bP' are the oblique offsets (see fig. 2.28). When the triangle abP is plotted, the apex point P will represent the position of the corner of the building.

Q.17. Describe cross-staff. ***(R.G.P.V., Feb. 2010)***

Ans. The cross-staff, is a simple instrument, which is used for setting out offsets to the chain line. This is also useful for setting out right angles. Cross-staffs are of the following three types –

(i) Open cross-staff
(ii) French cross-staff
(iii) Adjustable cross-staff.

Open cross-staff is the simplest type of cross-staff. It consists of a wooden or metal pieces or arms are provided with vertical slits for sighting through at right angles to each other. This whole assembly is called as head which is fixed to the top of an iron shoed wooden staff having 2.5 cm in diameter and 1.2 m to 1.5 m long, which is driven in to the ground. These cross staves are used for finding out the foot at a perpendicular offsets and for setting out a right angle at a point on a chain line. Fig. 2.29 shows the details of an open cross-staff.

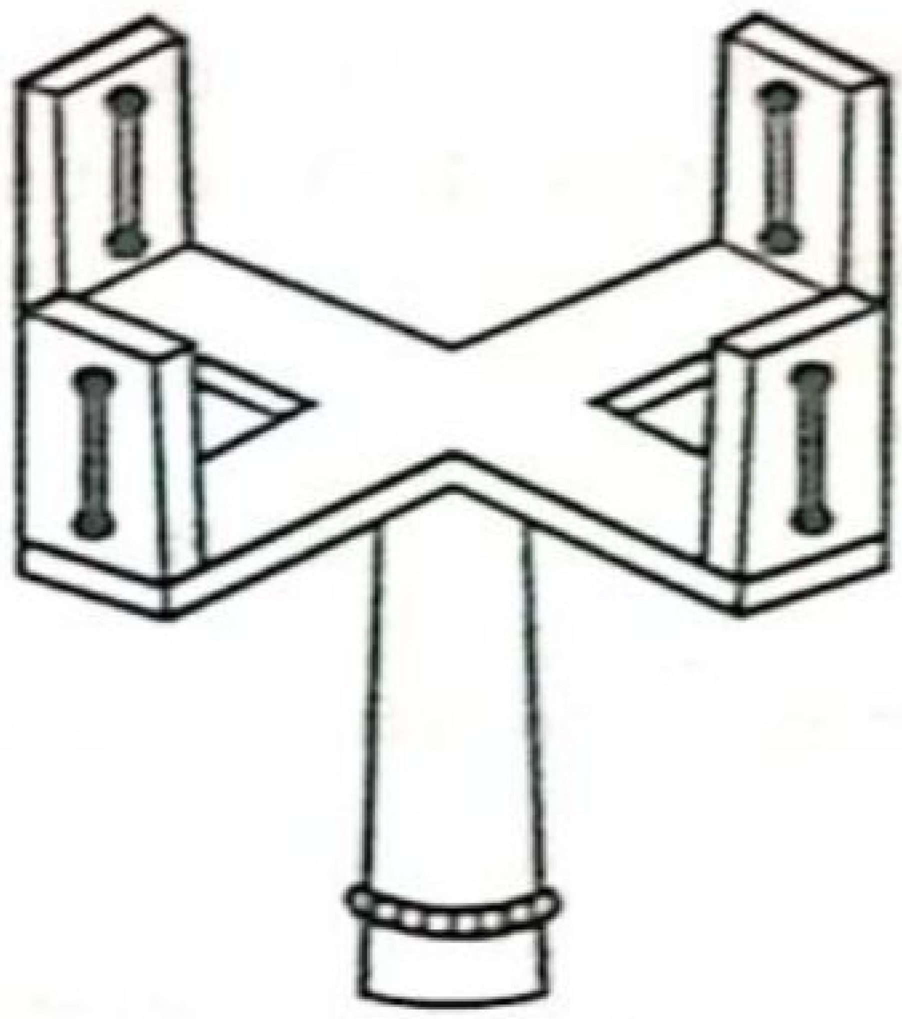


Fig. 2.29 Open Cross-staff

Q.18. Explain various obstacles encountered during chain survey. ***(R.G.P.V., June 2004, 2005, April 2009)***

Ans. Various types of obstacles generally met during chaining may be overcome by any one of the methods described here under.

The various obstacles may be classed as –

(i) Those which obstruct ranging but not chaining
(ii) Those which obstruct chaining but not ranging
(iii) Those which obstruct both ranging and chaining.

(i) Obstacles Which Obstruct Ranging but Not Chaining – In this type of obstacles, the ends of a line are not intervisible. Such obstacles are generally met in flat country where the area consists of rising grounds, intervening hills or undulations. Two cases may occur –

(a) Both ends are visible from intermediate points on the line.

(b) Both ends may not be visible from any intermediate point on the line.

Difficulties faced in both cases may be overcome by reciprocal ranging and random line methods.

(ii) Obstacles Which Obstruct Chaining but not Ranging – The typical types of obstruction under this category are such as water bodies, i.e. lakes, ponds, rivers etc. where the distance between two convenient points on the survey line on either side of the obstacle is required to be determined.

There may be two cases –

(a) In which it is possible to chain round the obstacle, e.g. a tank, pond, a bend in a river etc.

(b) In which it is not possible to chain round the obstacle, e.g. a river, a long lake etc.

Case I. Depending upon the layout of the obstacle and the nature of the terrain available round the obstacle for chaining, several methods can be employed. However, a few typical methods generally used are described as follows –

(a) By Constructing a Rectangle – (Fig. 2.30). At A and B, erect perpendiculars AD and BC of equal lengths. Join and measure DC which is equal to AB, the desired length.

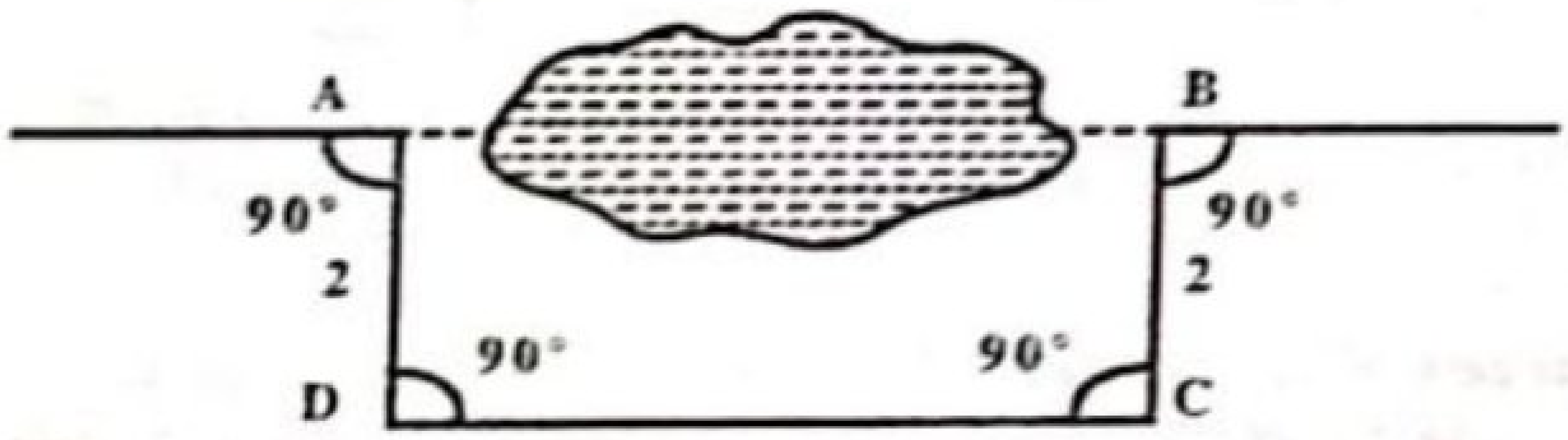


Fig. 2.30

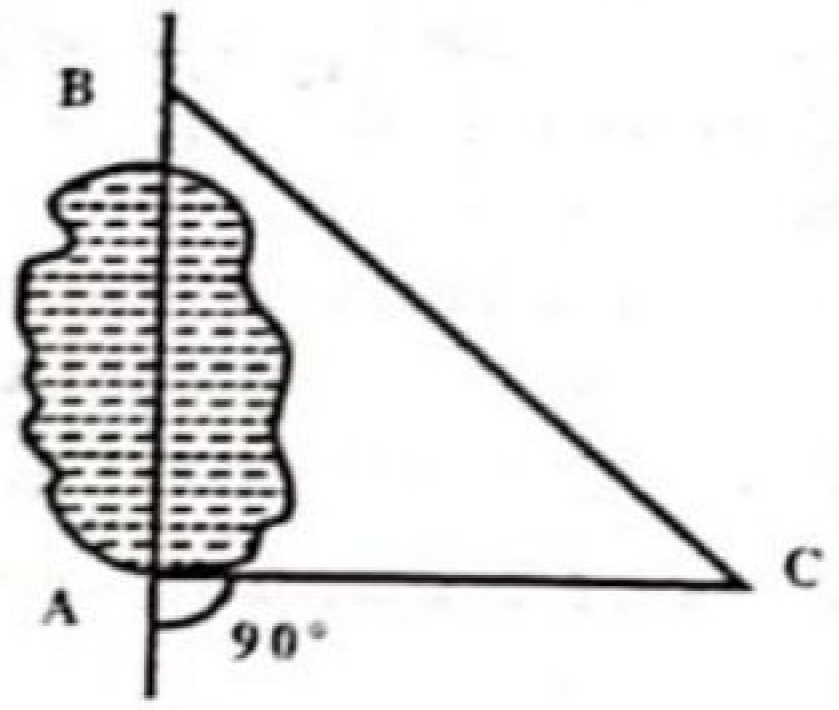


Fig. 2.31

(b) By constructing a Right Angled Triangle ABC Having 90° Angle at A or B – (Fig. 2.31). Erect a perpendicular AC of such a length so that CB is clear of the obstacle. Measure AC and CB accurately. The required length

$$
\begin{aligned}
AB &= \sqrt{(BC)^2 - (AC)^2} \\
&= \sqrt{(BC + AC)\,(BC - AC)}
\end{aligned}
$$

Case II – Few typical methods for overcoming the obstacles are described below –

By Construction of Similar Triangles – (Fig. 2.32)

(i) From A and C, another point on the chain line erect perpendiculars AD and CE such that points B, D and E are in a straight line. Measure AC, AD and CE; then $AB = \dfrac{AC \times AD}{CE - AD}$

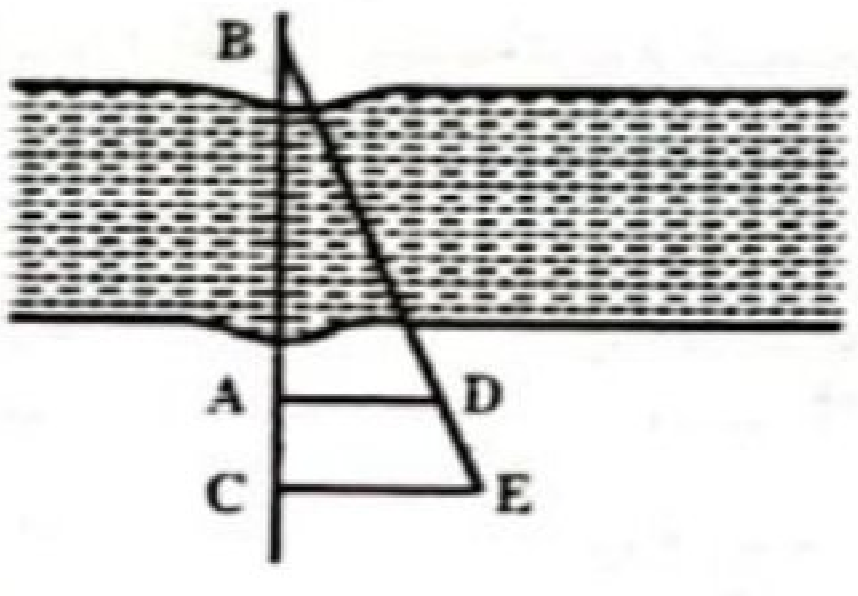


Fig. 2.32

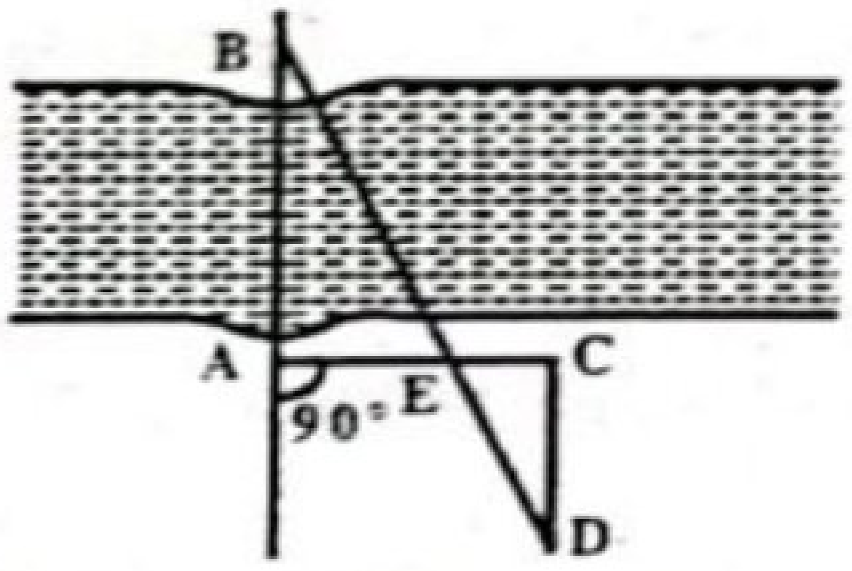


Fig. 2.33

(ii) Set out a perpendicular AC. Mark the mid-point of AC say E. Set out another perpendicular CD at C such that points B, E, and D lie on one line. Then AB = CD.

(iii) Obstacles Which Obstruct both Ranging and Chaining – In such cases prolonging the line beyond the obstacle and finding the distance across it may be overcome by any one of the methods explained here.

(a) From any two points A and B on the line, erect equal perpendiculars AC and BD. Range G and H in line with C and D. Set out GE and HF perpendiculars to CH and equal to AC. E and F are in the line and BE = DG. (Fig. 2.34)

(b) Erect a perpendicular AC. Mark a point B on the chain line such that AC = AB. Produce BC to D. Set out a right angle BDF. Measure DE equal to CD and EF equal to BC. From E and F swing arcs of radii equal to AC to get the location of G. Points G and F are along the chain line and CE may be measured to get the length AG. (Fig. 2.35).

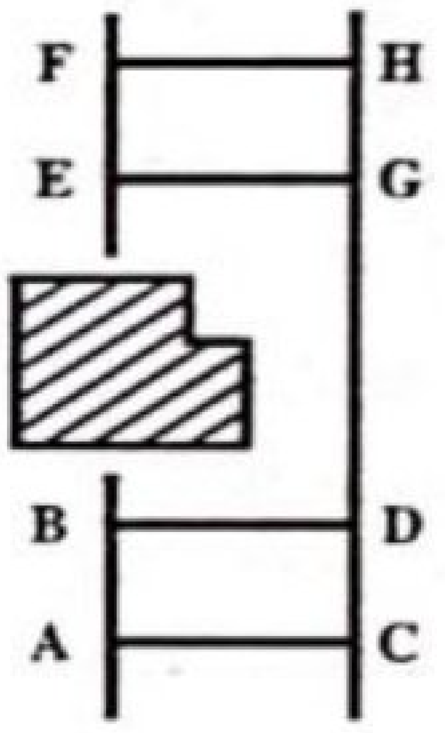


Fig. 2.34

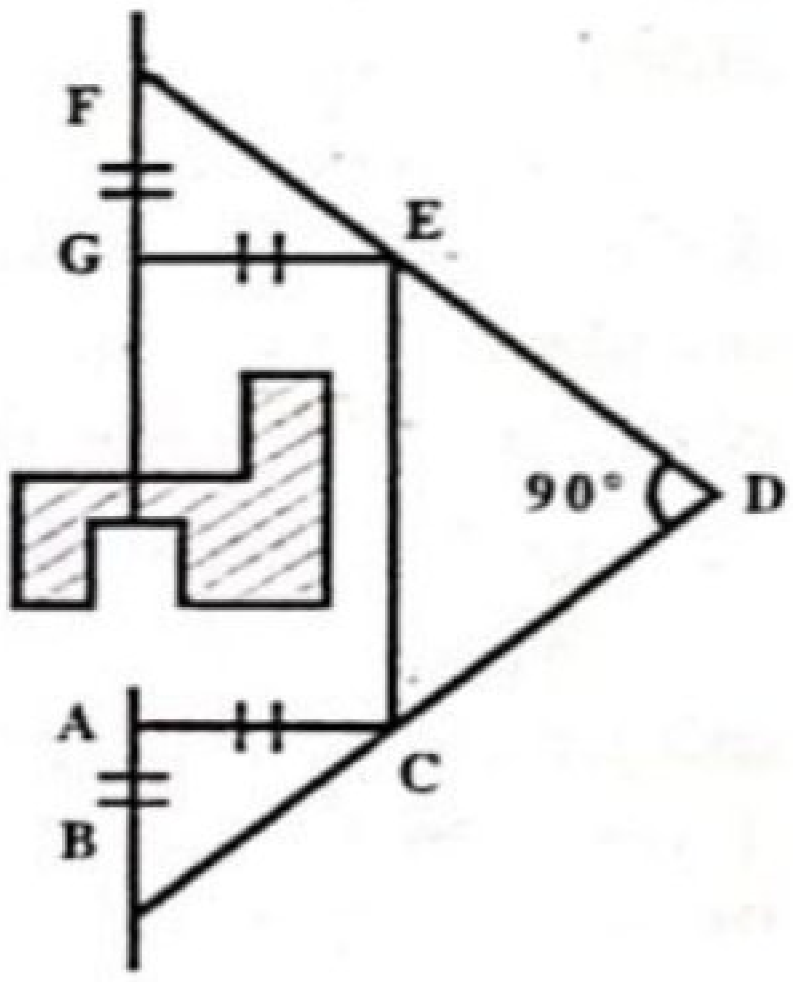


Fig. 2.35

Q.19. What are various sources of error in chain surveying ?
(R.G.P.V., Dec. 2010)

Ans. There are various sources of errors in chain surveying. Errors can be cumulative or compensating. Cumulative errors are those tend in addition as the measurement continue. Compensating errors are those which tend to become positive sometimes and negative at other times. The following errors in chaining should be avoided.

(i) In Correct Length of Chain – The actual length of chain used for measurement may be different from the designated length. The chain may be shorter or longer than the designated length. So that, length of the chain should be checked before the start of the survey and to be corrected before chaining.

(ii) In Correct Ranging – If the chain is placed out of the line while measuring a line, the measured length will always be more. So that, ranging should be correct before taking measurements.

(iii) Loose Chain – If chain is not pulled correctly while chaining the measured length will always be more. So that chain should be pulled correctly during chaining.

(iv) Temperature Change – If a chain or tape is standardized at some temperature and the temperature during measurement is much differ, there will be errors in the chaining due to change in length of chain or tape. This type of error should be compensated by correcting the length measured.

(v) Variation in Pull – If the pull applied during chaining is different from the standard pull, the length of the tape will change. So that during chaining pull should be applied correctly.

(vi) Errors in Slope Measurements – While measuring along a slope using the stepping method, the chain may not be straight during measurement which results in error. So that, chain should be kept straight while measuring along sloping ground.

(vii) Personal Mistakes – These mistakes are like, reading from the wrong end of chain, omitting a full chain length, reading in correctly the numbers on the tape and wrong booking of the length. These mistakes can be avoided with care during chaining, reading and recording.

Q.20. Write down the principle of compass.

Ans. The compass works on the principle that a freely suspended magnetic needle takes the direction of magnetic lines of force at a place. This gives us a reference direction with respect to which all angles can be measured.

The earth acts as a powerful magnet. The lines of force of earth's magnetic field run generally from south to north. Near the equator, they are parallel to the earth's surface.

When a magnetic needle balanced at the centre of its length, it swings freely in a horizontal plane and ultimately rests along N – S direction of the earth magnetic field. The earth magnet poles do not coinside with the geographical poles and hence the N – S direction given by magnetic needle (megnetic meridian) is not the true meridian or the N – S direction of the geographical pole.

Q.21. Write short note on – Magnetic compass.

Ans. Magnetic compass gives directly the magnetic bearings of lines. The bearings are measured either in W.C.B. system or R.B. system, depending upon the form of compass used. The principle of all magnetic compasses are that if a long, narrow strip of a steel or iron is magnetised and if it is suspended on the pivot and leaves freely then it will established itself in the magnetic meridian.

Magnetic compass consists of magnetic needle, a line of sight, a graduated circles, a compass box.

Q.22. What are the different types of compass ? Explain with neat sketch.

Or

Describe in brief compass equipments along with their use.

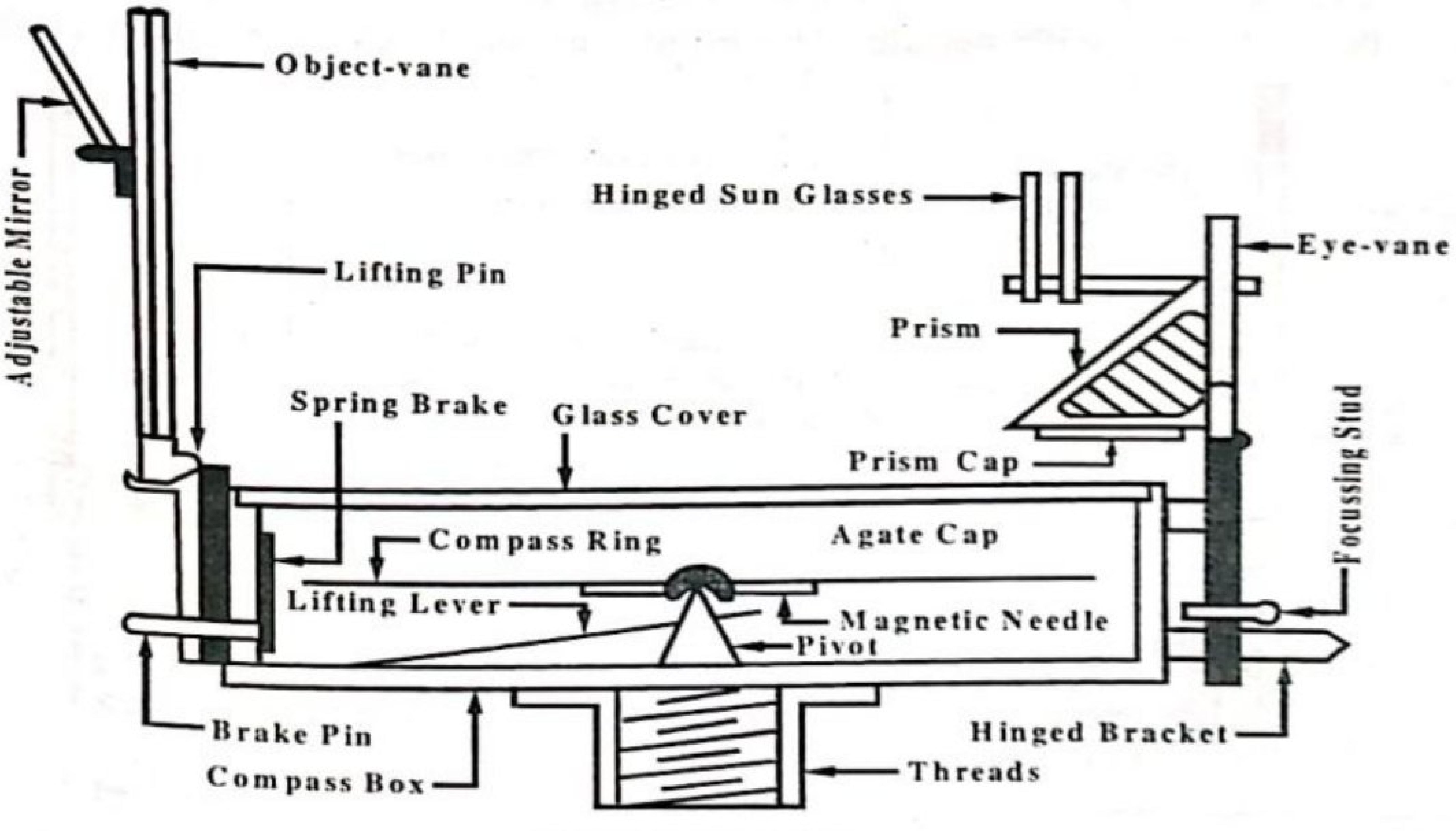
(R.G.P.V., Dec. 2010)

Ans. There are two types of compass –

(i) Prismatic compass (ii) Surveyor's compass.

(i) Prismatic Compass – The prismatic compass is the most convenient, handy and portable instrument. It is circular in shape and its diameter varies from 85 mm to 110 mm. It is made up of a non-magnetic metal. Fig. 2.36 shows the typical section of a prismatic compass. It essentially consists of the following parts –

(a) A magnetic needle of broad type supported over a centrally situated pivot made of hard steel is provided.



Prismatic Compass

Fig. 2.36 Prismatic Compass

(b) A graduated aluminium ring is attached with the needle and it is divided into degress and half-degrees. The graduations start from zero marked at south end of the needle and they run clockwise so that 90°. 180° and 270° are marked respectively at west, north and east. The figures are written inverted.

(c) The eyevane and object vane are fixed diametrically opposite to each other. The reflecting prism is provided near eye vane. The line joining eye vane and object vane passes through the centre of compass.

(d) The focussing stud is provided to adjust the eye sights of the different persons.

(e) A break pin is provided to stop the oscillations of the ring.

(f) A glass cover is provided at the top so that dust particles cannot enter the compass box.

(g) The sun-glasses are provided to facilitate the sighting of objects in sunlight.

(h) A hinged mirror with sighting or object vane is provided. The mirror can be inclined at any angle so that it becomes possible to sight the objects which are too low or too high.

(ii) Surveyor's Compass – It is similar to the prismatic compass with some exceptions. In this compass the graduated ring is directly attached to the box and not with needle. The edge bar needle freely floats over the

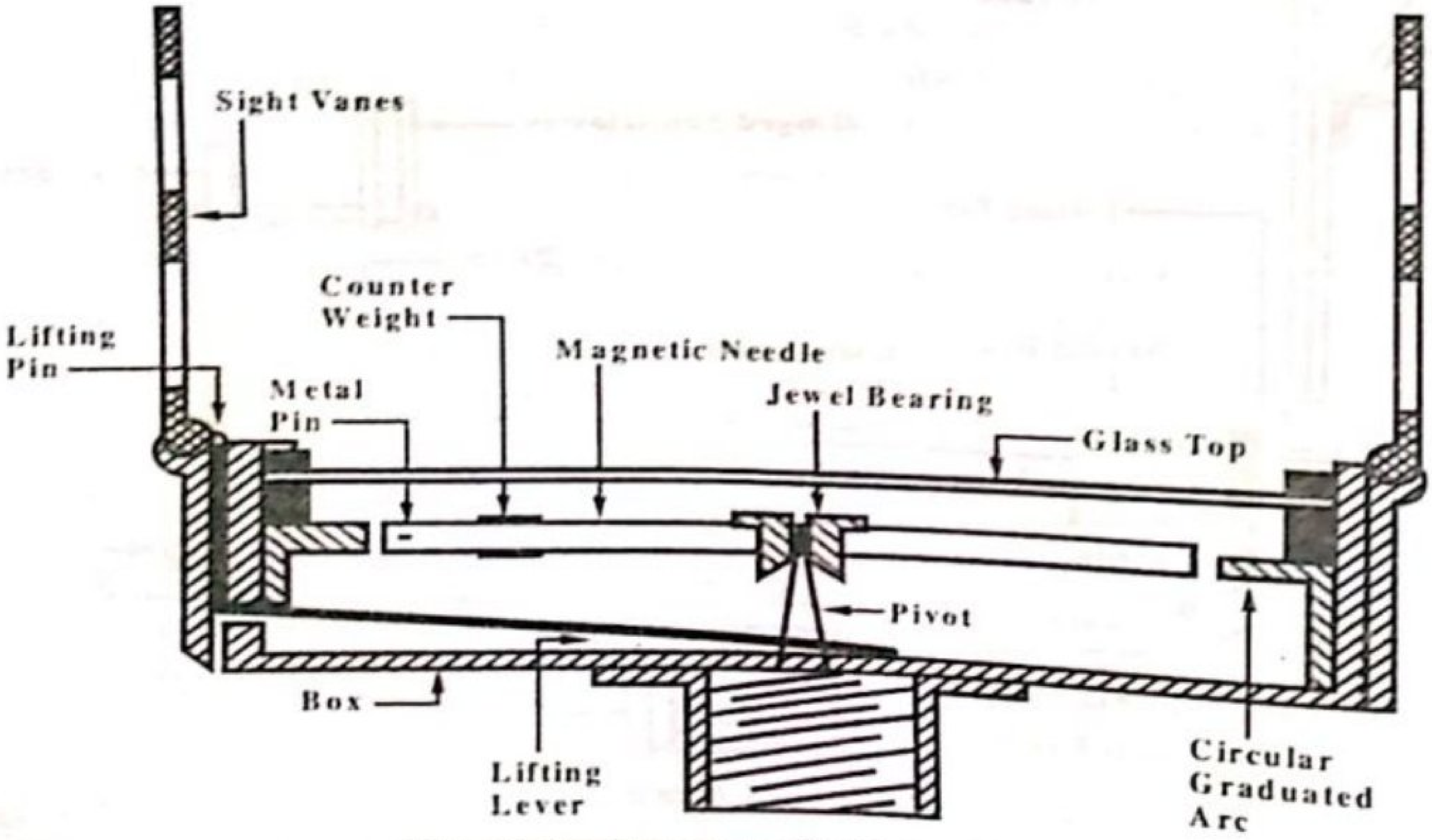


Fig. 2.37 Surveyor's Compass

pivot. There is no prism. The object vane is similar to prismatic compass, but eyevane consists of a simple metal vane with fine slit. In the object is sighted first with object & eye vanes and the reading is then taken by looking vertically through the top of glass. The graduated figures are written in the right way up. The ring is graduated from 0° – 90° in our quadrants with 0° at N and S ends and 90° at E & W ends. The letters E (East) and W (West) are interchanged from their true positions.

Q.23. Compare between prismatic and surveyor's compass.
(R.G.P.V., June 2005, Dec. 2005, 2011)

Ans. Comparison between surveyor's and prismatic compass is given in table 2.2.

Table 2.2

S.No.	*Feature*	*Prismatic Compass*	*Surveyor's Compass*
(i)	Magnetic needle	A broad type needle is used.	An edge bar needle is used.
(ii)	Graduations	(a) The graduations are in W.C.B. system.	(a) The graduations are in R.B. system.
		(b) Graduated ring attached to the needle.	(b) Graduated ring attached to the box.
(iii)	Sight vanes	(a) Object vane consists of vane with a vertical hair.	(a) Object vane consists of metal vane with a vertical hair.
		(b) Eye vane consists of a small metal vane with slit near the prism.	(b) Eye vane consists of a metal vane with the fine slit.
(iv)	Reading	(a) Reading and sighting both can be done simultaneously from one position of the observer.	(a) Sighting and reading are done separately from different positions.
		(b) The reading is taken with the help of a prism provided at the eye slit.	(b) The reading is taken by directly viewing through the top of the glass.
(v)	Support	(a) The compass can be held in hand while taking observations.	(a) The compass cannot be used without a support.
		(b) Tripod may or may not be used.	(b) The support can be a tripod.

Q.24. What do you understand by compass surveying ?

Ans. The branch of surveying in which directions of survey lines are determined by a compass and their lengths by chaining or taping is called as compass surveying.

If the area to be surveyed is small then chain surveying is preferred but if the area to be surveyed is large, compass survey is preferred.

Q.25. What do you understand by traverse ? Explain their types.

Or

Write short note on – Closed traverse and Open traverse.

(R.G.P.V., Nov./Dec. 2007)

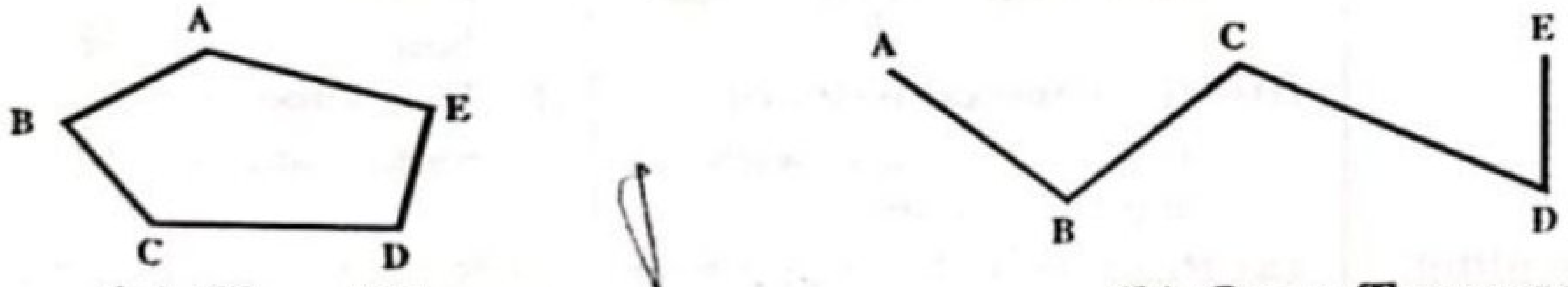
Ans. A series of connected straight lines whose lengths and directions are known is called as a traverse. The word traverse means to pass across. In the process of traversing, the direction of the survey line is fixed by taking the angular measurements, with suitable instruments and distance by chaining of taping.

Types of Traverse – The traverse may be classified into two types –

(i) Closed traverse (ii) Open traverse.

(i) Closed Traverse – The traverse, which returns to its starting station or to the another whose location is already known is called as closed traverse. Fig. 2.38 (a).

(ii) Open Traverse – The traverse, which does not returns to its starting station or to the another station is called as on open traverse. It consists of a series of connected links. Fig. 2.38 (b) shows an open traverse.



(a) Closed Traverse ***(b) Open Traverse***

Fig. 2.38

Q.26. Define balancing the traverse. Explain various methods of balancing the traverse.

Ans. Balancing the traverse is the process of adjusting consecutive co-ordinates of each line by applying corrections to them in such a way that the algebraic sum of the latitudes as well as algebraic sum of the departures should be equal to zero. This applies only when the survey forms a closed polygon.

Following are the common methods of adjusting a traverse –

(i) Arbitrary method (ii) Bowditch's method

(iii) Transit method (iv) Axis method.

(i) Arbitrary Method – The arbitrary method is simple and logical, as it provides a logical proportion of the correction based on the accuracy of each measurement. In this method, the linear misclosure is distributed arbitrarily according to the discretion of the surveyor based on the field conditions. Thus the misclosure is distributed in a discretionary manner to close the figure geometrically.

(ii) Bowditch's Method – On the basis of this method, there are two assumptions –

(a) The error in linear measurements are proportional to $\sqrt{l}$.

(b) The error in angular measurements are inversely proportional to $\sqrt{l}$.

where l = Length of line.

In a closed traverse the sum of latitudes and departures should be equal to zero. If one or both are not zero then corrections are applied as follows –

Correction to latitude or departure of any side

$$= \text{Total error in latitude or departure} \times \frac{\text{Length of that side}}{\text{Perimeter of traverse}}$$

If, δL = Correction to latitude of any side

δD = Correction to departure of any side

ΣL = Total error in latitude

ΣD = Total error in departure

Σl = Length of perimeter

l = Length of any side.

We have

$$\delta L = \Sigma L \times \frac{l}{\Sigma l} \text{ and } \delta D = \Sigma D \times \frac{l}{\Sigma l}$$

(iii) Transit Method – This method assumes that the angles are measured to greater precision than the lengths. According to this rule, the total error in latitudes and in departures is distributed in proportion to the latitudes and departure of the side.

Correction to latitude of a line

$$= \text{Total error in latitude} \times \frac{\text{Latitude of the line}}{\text{Arithmetic sum of latitudes}}$$

Correction to departure = Total error in departure of a line

$$\times \frac{\text{Departure of the line}}{\text{Arithmetic sum of departures}}$$

(iv) Axis Method – In the axis method, the corrections are applied only to lengths. The method is used to balance a traverse in which the angles are measured very precisely whereas the distances are not measured so precisely. In the axis method, as the directions of the lines are unaffected, the general shape of the traverse does not change.

The following procedure is used for adjusting a closed traverse ABCDE by the axis method –

(a) Plot the traverse A'B'C'D'E'A'$_1$, starting from the initial point A', but ends at the point A'$_1$.

(b) Join points A'$_1$ and A', and produce the line A'$_1$A to cut the line C'D' at X. The line A'$_1$X is known as the axis. The axis divides the traverse approximately into two equal parts.

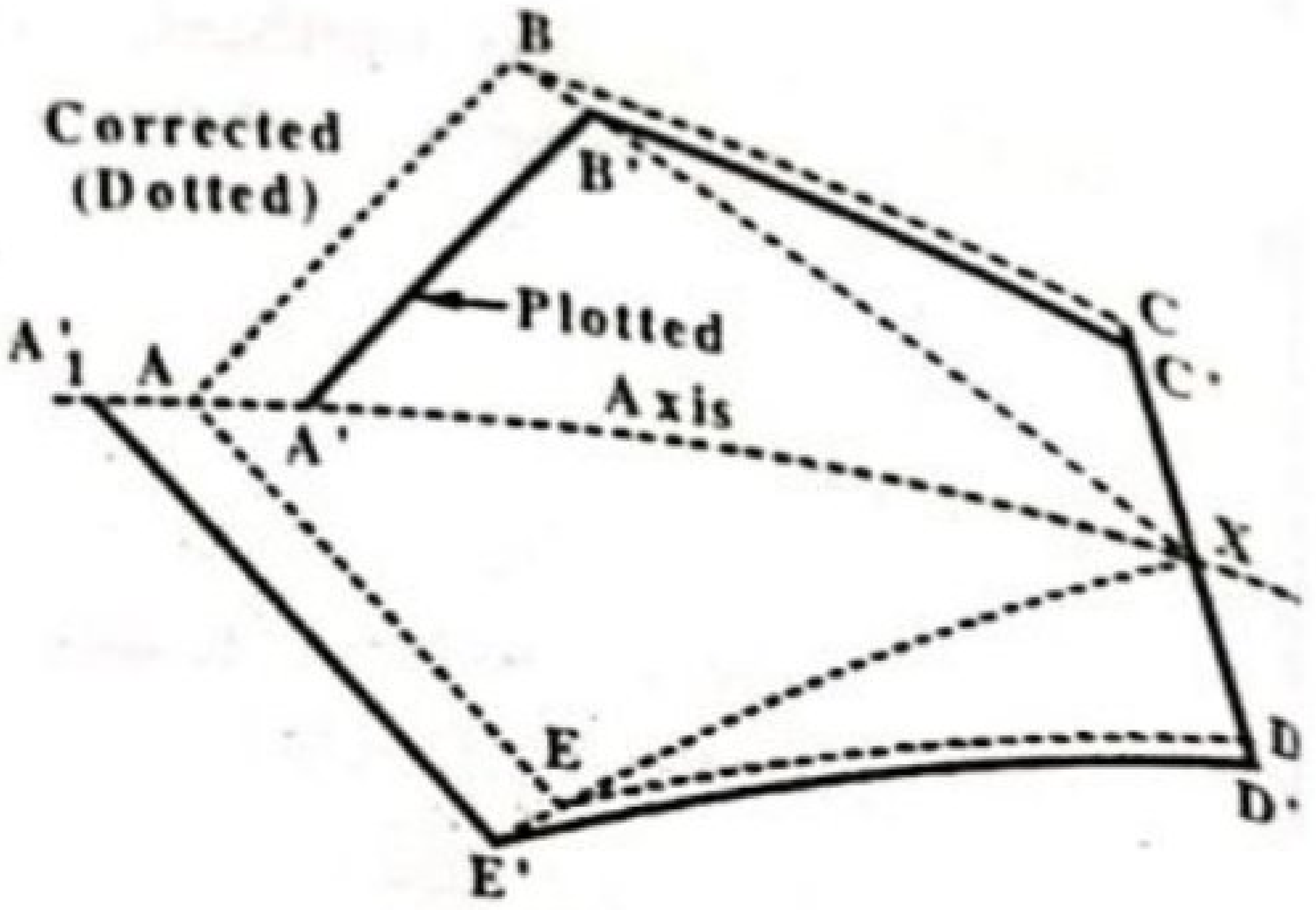


Fig. 2.39

(c) Bisect the line A'$_1$A', and locate its middle point A.

(d) Draw a line AB through A and parallel to A'B', cutting XB produced at B.

(e) Draw the line BC through B and parallel to B'C', cutting th XC' produced at C.

(f) Draw a line AE through A and parallel to A'$_1$E' cutting XE' at E

(g) Draw a line ED through E and parallel to E'D', cutting XD at D.

The figure ABCDEA is the adjusted traverse. In the axis method, th correction to any line is given by

$$= \frac{\text{One-half the closing error}}{\text{Length of the axis A'X}} \times \text{Length of that line}$$

Q.27. Write short note on Bowditch's rule. ***(R.G.P.V., Dec. 2017***

Ans. Refer Q.26 (ii).

Q.28. What do you understand by meridian ?

(R.G.P.V., Nov./Dec. 2007, June 2009

Ans. **Meridian** – The direction of a line is defined by the horizontal angl which the line makes with a reference line. Thus the direction is the angul relationship of one line to another line. Generally, directions are measure clockwise from the reference line. The fixed line of reference is called meridian.

There are four types of meridians used in surveying –

(i) True meridian	(ii) Magnetic meridian
(iii) Grid meridian	(iv) Arbitrary meridian.

(i) True Meridian – The line joining the geographical north and sout poles is known as the true meridian or geographic meridian. The direction a true meridian never changes and hence, azimuth of a line remains constan

The true meridian at a point may be taken as a line in the plane passing through the point P and the north and south poles of the earth. The geographical poles are the points of intersection of the earth's axis and the surface of the earth. The geographical poles are also known as true poles. The true meridian at a point can be determined by astronomical observations to the sun or stars.

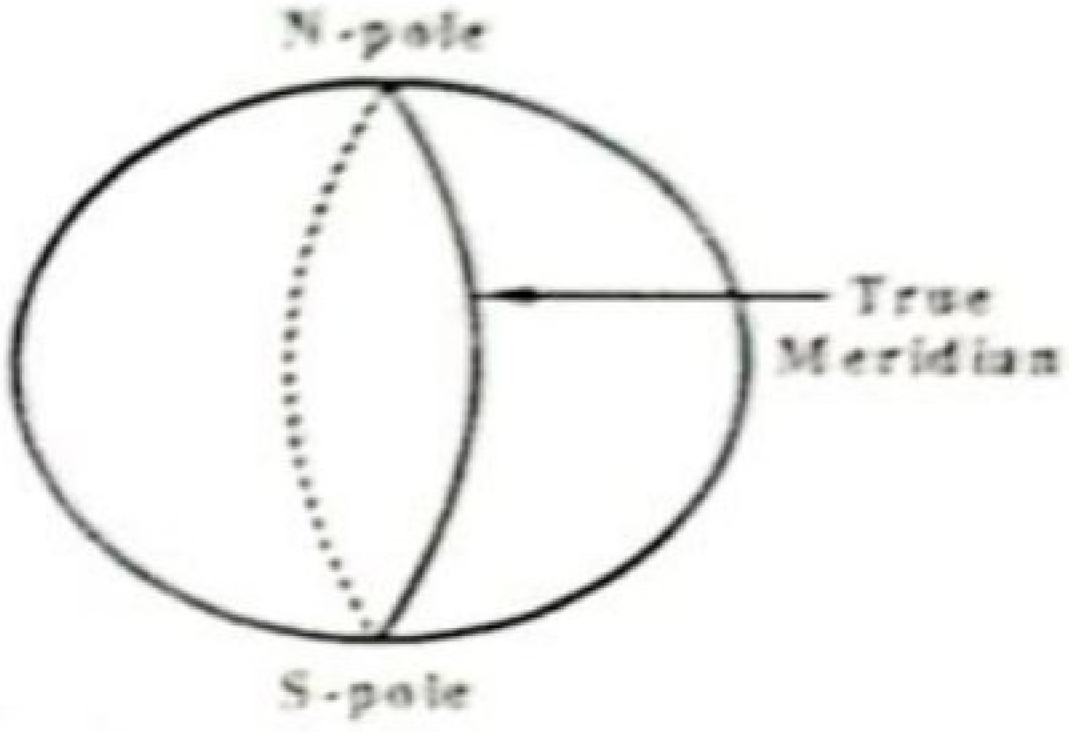


Fig. 2.40 True Meridian

(ii) Magnetic Meridian – Magnetic meridian at a point is the direction of freely floating and balanced magnetic needle free from all other attractive forces. The freely suspended needle is parallel to the line passing through the magnetic north and south poles and hence it indicates the direction of the magnetic meridian at that place.

(iii) Grid Meridian – For survey of a state, the true meridian of a central place is sometimes taken as a reference meridian for the whole state. Such a reference meridian is called the grid meridian.

(iv) Arbitrary Meridian – Arbitrary meridian is any convenient direction towards a permanent and prominent mark or signal. These signals may be any church, chimney etc.

Q.29. What do you understand by bearing ? ***(R.G.P.V., June 2009)***

Or

Define bearing of a line. ***(R.G.P.V., Dec. 2015)***

Or

What do you understand by the term bearing of a line ? ***(R.G.P.V., June 2016)***

Ans. The bearing of a line is the horizontal angle which it makes with a reference line or meridian.

Types of Bearings – There are four types of bearings depending upon the meridian –

(i) True Bearing – The true bearing of a line is the horizontal angle between the true meridian and the line.

(ii) Magnetic Bearing – The magnetic bearing of a line is the horizontal angle between the magnetic meridian and the line.

(iii) Grid Bearing – The grid bearing of a line is the horizontal angle which the line makes with the grid meridian.

(iv) Arbitrary Bearing – The arbitrary bearing of a line is the horizontal angle which the line makes with the arbitrary meridian.

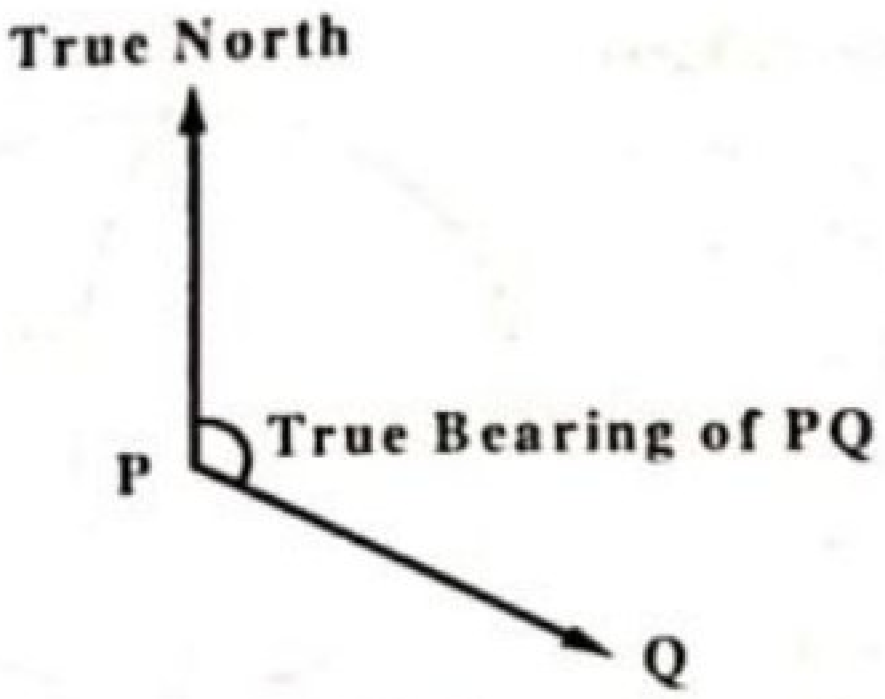


Fig. 2.41 True Bearing

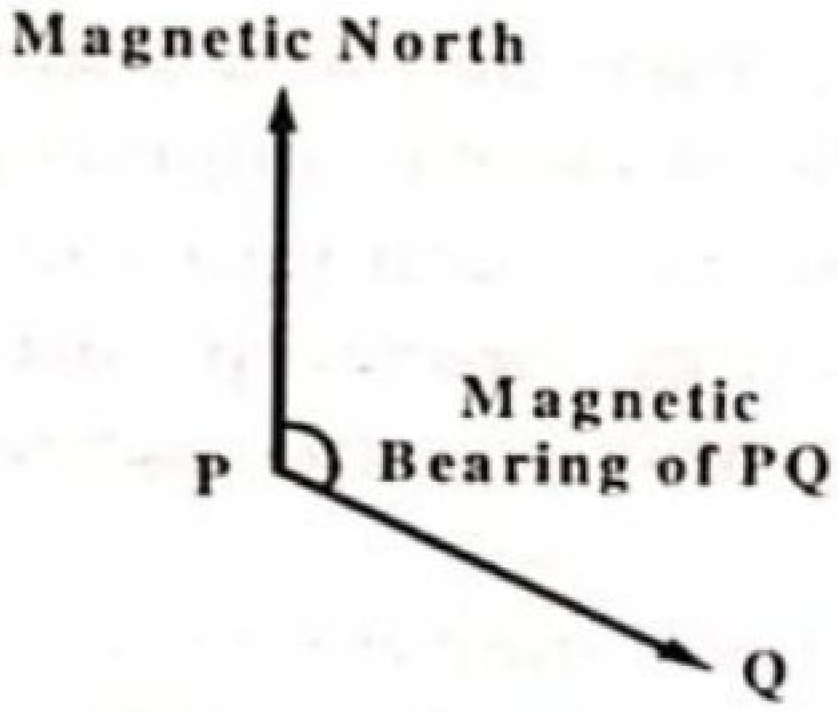


Fig. 2.42 Magnetic Bearing

Q.30. Discuss various systems of designation of bearings.

Ans. The bearing of a line can be designated in the following systems

(i) Whole circle bearing system

(ii) Quadrantal or reduced bearing system.

(i) Whole Circle Bearing System – In this system, the angle i measured from the magnetic north in clockwise direction and its value wil therefore vary from 0° to 360°, as shown in fig. 2.43.

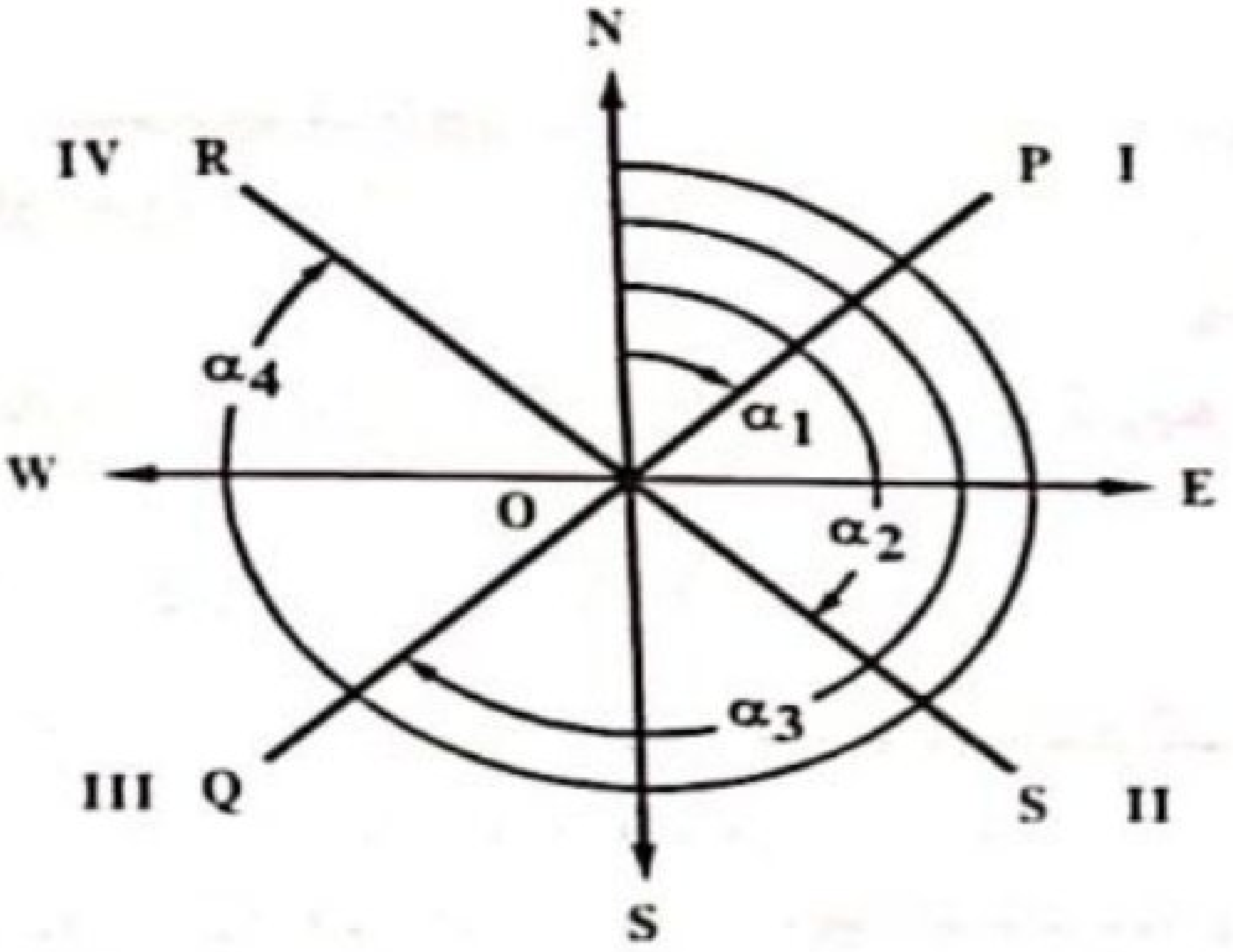


Fig. 2.43 Whole Circle Bearing System

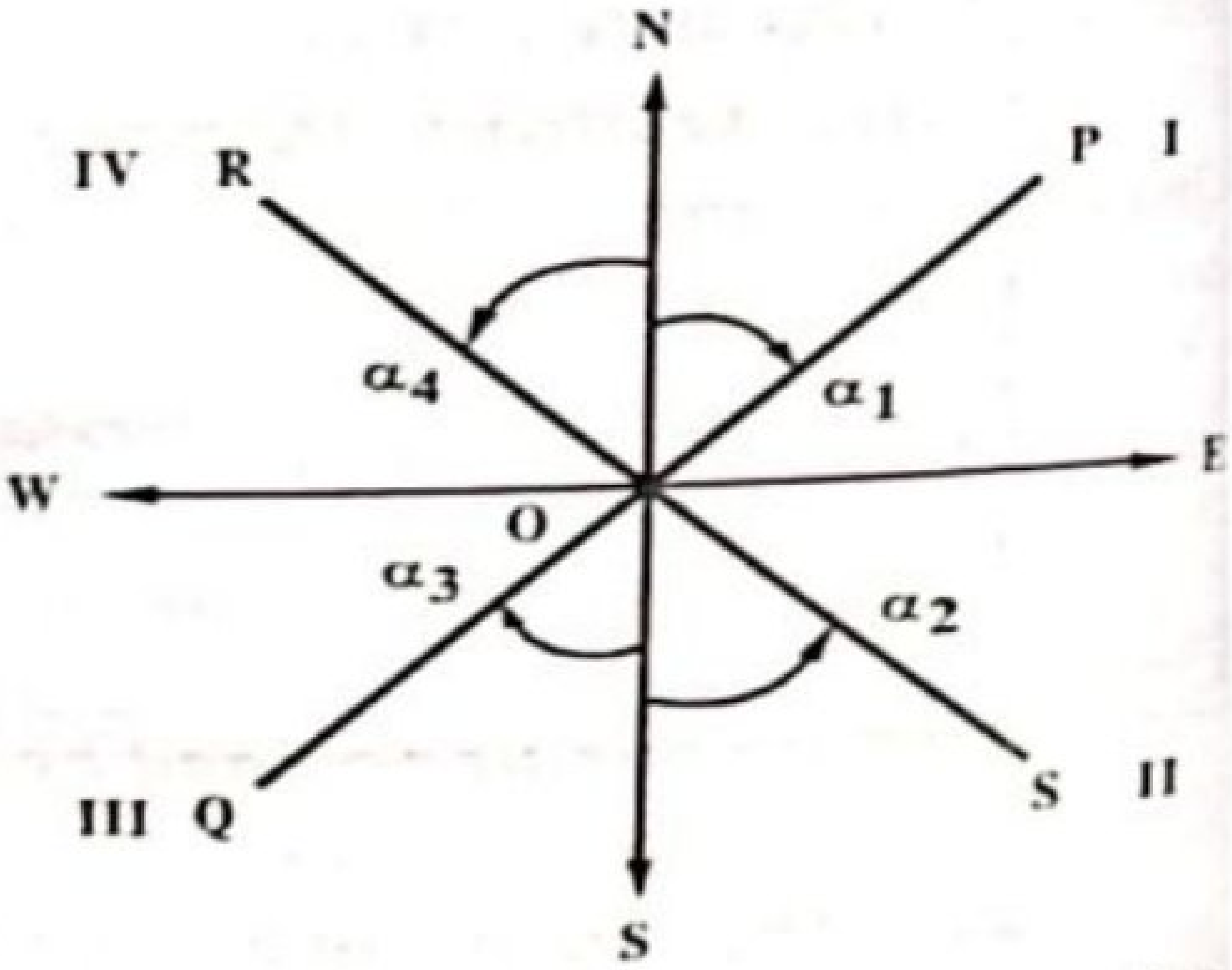


Fig. 2.44 Quadrantal or Reduced Bearing System

Whole circle bearing of OP = α_1

Whole circle bearing of OS = α_2

Whole circle bearing of OQ = α_3

Whole circle bearing of OR = α_4

One point should always be keep in mind that, the angle is always taken in clockwise direction from magnetic north.

(ii) Quadrantal or Reduced Bearing System – In this system, angle is measured from north or south to east or west. Thus, in this system numerical value of angle does not exceeds 90°. It has to be cleared that in reduced bearing system, the bearings are never reckoned from the E and W direction and hence, the letter which precedes the figure must be either N or S.

The reduced bearing of line OP will be written as N α_1 E, that means the bearing being measured with reference to north meridian towards east. Similarly, the reduced bearings of OS, OQ, OR are S α_2 E, S α_3 W, N α_4 W respectively.

Thus, in the quadrantal or reduced bearing system, the reference meridian (north or south) is prefixed and the direction of measurement (east or west) is affixed to the numerical value of the bearing.

Q.31. Distinguish between whole circle bearing system and reduced bearing system.

Ans. Differences between whole circle bearing system and reduced bearing system are given in table 2.3.

Table 2.3

S.No.	*Whole Circle Bearing System*	*Reduced Bearing System*
(i)	In this system bearings are always taken in clockwise direction from magnetic north.	In this system bearings are taken either from magnetic north or magnetic south which one is nearer to the line.
(ii)	Direction of angle (or bearings) are always taken in clockwise direction.	Direction of angle (or bearings) may be clockwise or anticlockwise depends upon condition.
(iii)	In this system bearings varies from 0° to 360°.	In this system bearing varies from 0° to 90°.

Q.32. How bearings can be converted from one system to another system ?

Ans. The whole circle bearing of a line can be easily converted into reduced bearing and vice versa. Referring to fig. 2.43, the conversion of W.C.B. into R.B. can be expressed in the following table –

Table 2.4 Conversion of W.C.B. into R.B.

Line	*Quadrant*	*W.C.B.*	*Rule for R.B.*	*R.B.*
OP	I	$\alpha_1 = 0^\circ$ to 90°	R.B. = W.C.B.	N α_1 E
OS	II	$\alpha_2 = 90^\circ$ to 180°	R.B. = 180° – W.C.B.	S $(180^\circ - \alpha_2)$ E
OQ	III	$\alpha_3 = 180^\circ$ to 270°	R.B. = W.C.B.– 180°	S $(\alpha_3 - 180^\circ)$ W
OR	IV	$\alpha_4 = 270^\circ$ to 360°	R.B. = 360° – W.C.B.	N $(360^\circ - \alpha_4)$ W

Referring to fig. 2.44, the conversion of R.B. into W.C.B. can be expressed in the following table –

Table 2.5 Conversion of R.B. into W.C.B.

Line	*Quadrant*	*R.B.*	*Rule for W.C.B.*	*W.C.B.*
OP	I	N α_1 E	W.C.B. = R.B.	α_1
OS	II	S α_2 E	W.C.B. = 180° – R.B.	$180^\circ - \alpha_2$
OQ	III	S α_3 W	W.C.B. = 180° + R.B.	$180^\circ + \alpha_3$
OR	IV	N α_4 W	W.C.B. = 360° – R.B.	$360^\circ - \alpha_4$

Q.33. What do you understand by fore and back bearing of a line ? Explain its relationship.

Or

Write short note on fore bearing and back bearing of a line.

(R.G.P.V., Dec. 2017)

Ans. Any straight line has two opposite directions, depending upon the direction of arrow. The bearing of a line in the direction of the progress of survey is called the fore bearing. The bearing of the line in the direction opposite to the direction of progress of survey is called back bearing.

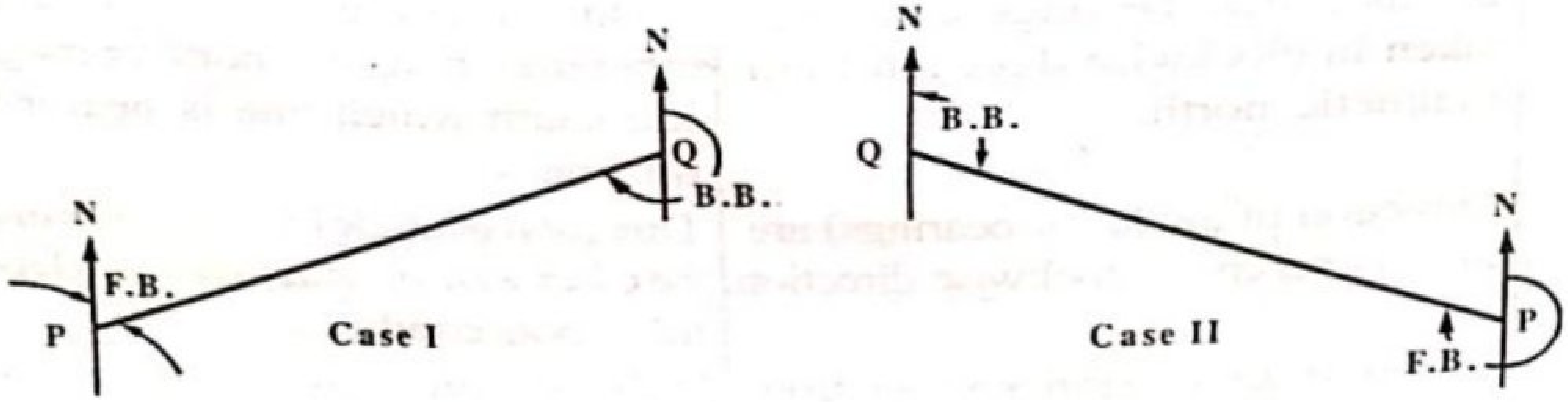


Fig. 2.45 Fore and Back Bearing

Every line has two bearings namely, fore bearing and back bearing. Referring fig. 2.45, whenever reading is taken from P, that will be the F.B. of line PQ and whenever reading is taken from Q, that will be the B.B. of line PQ. Whenever, W.C.B. system is adopt for finding out relationship between F.B. and B.B. of given line PQ. For case I, as shown in fig. 2.45.

B.B. = F.B. + 180°

For case II, as shown in fig. 2.45,

B.B. = F.B. – 180°

Thus, a general expression is as follows –

B.B. = F.B. ± 180°

Use + sign when F.B. is less than 180° and – sign when F.B. is greater than 180°.

Whenever, R.B. system or quadrantal system is adopted, there will not be any change in the values of F.B. and B.B. except that their respective quadrants will be interchanged. Thus, if F.B. is in NE quadrant, B.B. will be in SW quadrant. Thus, N is to be substituted for S and E is to be substituted for W and so on.

Q.34. Differentiate between fore bearing and back bearing.
(R.G.P.V., June 2004)

Ans. Differences between fore bearing and back bearing are given in table 2.6 –

Table 2.6

S.No.	*Fore Bearing*	*Back Bearing*
(i)	It is the bearing of line in the direction of progress of the line.	It is the bearing of line in the opposite direction of progress of the line.
(ii)	Formula for findout F.B. is F.B. = B.B. ± 180°	Formula for findout B.B. is B.B. = F.B. ± 180°

Q.35. How will you calculate the included angles if bearings of lines are given in whole circle bearing system ?

Ans.

$$\boxed{\text{Included angle} = \text{Bearing of next line} - \text{Bearing of preceding line}}$$

For finding out the included angles between any lines, above mentioned formula is used. Consider a closed traverse as shown in fig. 2.46.

By referring the figure

$\angle A$ = Bearing of line AB – Bearing of line AD

$= 120^\circ - (180^\circ + 30^\circ)$

($\because$ Bearing of line AD = Bearing of line DA + 180°)

$= -90^\circ = \mathbf{90^\circ}$ (anticlockwise) (–ve)

$\angle B$ = Bearing of line BC – Bearing of line BA

$= 190^\circ - (180^\circ + 120^\circ)$

$= -110^\circ = \mathbf{110^\circ}$ (anticlockwise) (–ve)

$\angle C$ = Bearing of line CD – Bearing of line CB

$= 272^\circ - (190^\circ - 180^\circ) = 272^\circ - 10^\circ$

$= 262^\circ$ (Exterior angle) (+ve)

Hence Interior angle

$= 360^\circ$ – Exterior angle

$\therefore$ Interior angle $\angle C$

$= 360^\circ$ – Exterior angle

$\angle C = 360^\circ - 262^\circ$

$= \mathbf{98^\circ}$ (Interior angle) (+ve)

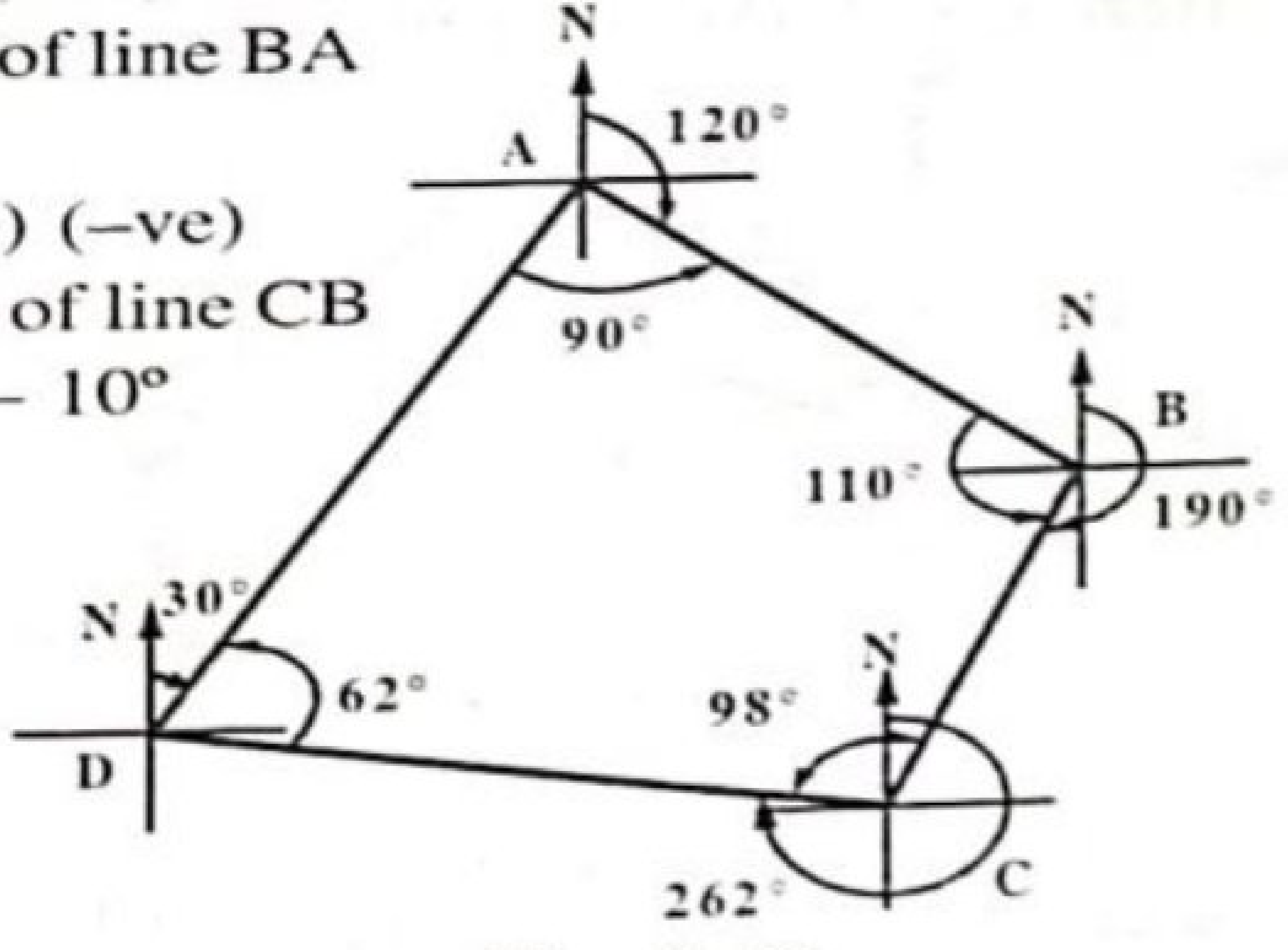


Fig. 2.46

$\angle D =$ Bearing of line DA – Bearing of line DC

$= 30^\circ - (272^\circ - 180^\circ)$

$= 62^\circ$ (Interior angle) (–ve)

CHECK $= \angle A + \angle B + \angle C + \angle D = 360^\circ$

Note –

(i) If direction of traverse is clockwise then the direction of included angle will be anticlockwise (with –ve sign)

(ii) If direction of traverse is anticlockwise then the direction of included angle will be clockwise (with +ve sign)

(iii) If direction of traverse is clockwise then the direction of included angle should be anticlockwise (with –ve sign). If it comes clockwise (with the +ve sign) that means it is the exterior angle, then for finding out the interior angle, reduce the exterior angle from 360°.

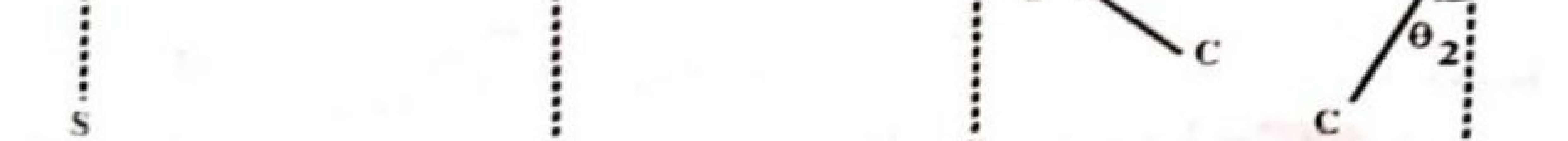
Q.36. How will you calculate the included angles if bearings of lines are given in reduced (Quadrantal) bearing system ?

Ans. A neat diagram may be drawn and the bearings of the lines plotted in their respective quadrants. The included angle is calculated from one of the undermentioned formulae.

(i) [Fig. 2.47 (a)]. If the bearings have been measured to the same side of the common meridian, the included angle $\alpha = \theta_2 - \theta_1$ i.e. the difference of the bearings. This is true for all the quadrants.

(ii) [Fig. 2.47 (b)]. If the bearings have been measured to the opposite side of the common meridian, the included angle $\alpha = \theta_1 + \theta_2$ i.e. the sum of the bearings.

(iii) [Fig. 2.47 (c)]. If the bearings have been measured to the same side of the different meridians, the included angle $\alpha = 180^\circ - (\theta_1 + \theta_2)$ i.e. the difference of 180° and the sum of the bearings.



(a) (b) (c) (d)

Fig. 2.47

(iv) [Fig. 2.47 (d)]. If the bearings have been measured to the opposite side of different meridians, the included angle $\alpha = 180^\circ - (\theta_1 - \theta_2)$ i.e. the difference of 180° and the difference of the bearings.

Q.37. How will you find out the bearing of the lines, if included angles are given ?

Ans.

Bearing of next line = Bearing of preceding line + Included angle

For finding out the bearings of lines, above mentioned formula is used. Consider a closed traverse as shown in fig. 2.48.

In this case, atleast bearing of any one line as well as all the included angles should known for finding out the bearings of another lines.

Suppose bearing of line AB is given and equal to 30°, angles are given as $\angle A = 120^\circ$, $\angle B = 80^\circ$, $\angle C = 60^\circ$, $\angle D = 100^\circ$

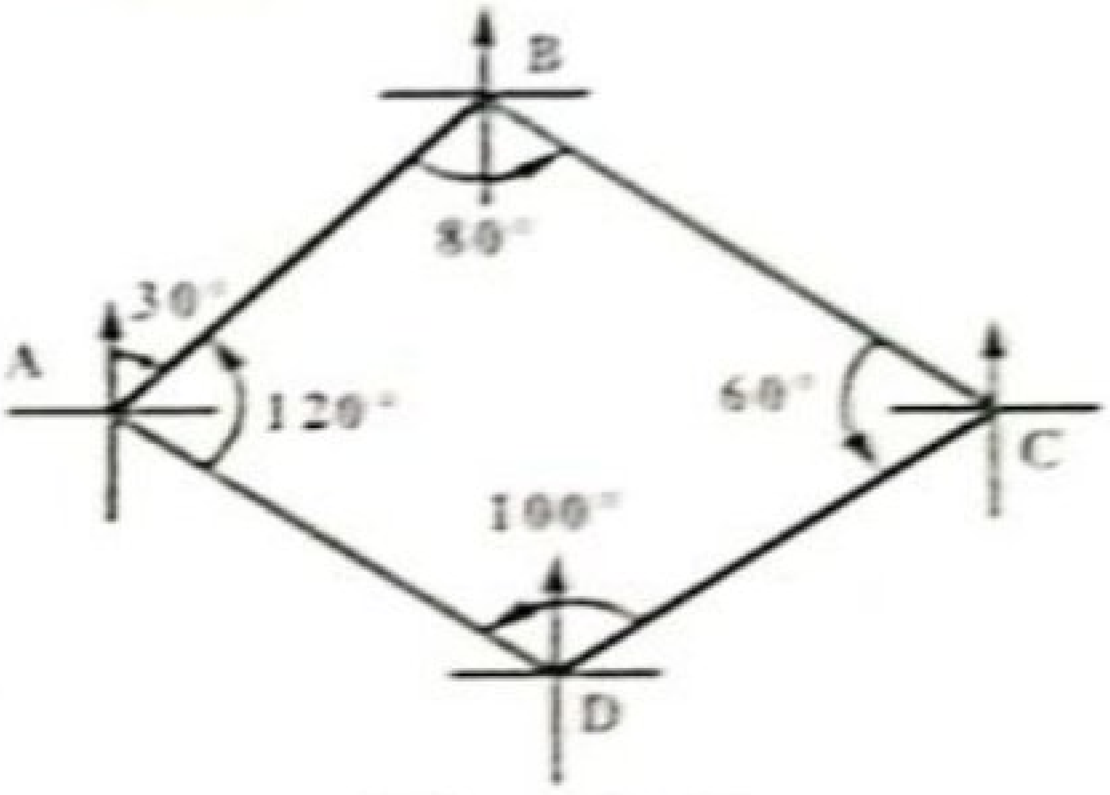


Fig. 2.48

Fore bearing of line AB $= 30^\circ$ (given)
Back bearing of line AB $= (30^\circ + 180^\circ) = \mathbf{210^\circ}$
Bearing of next line = Bearing of preceding line + Included angle
Fore bearing of line BC = Bearing of line BA + Included angle $\angle$ B
$= (180^\circ + 30^\circ) + (-)\ 80^\circ = \mathbf{130^\circ}$

{As direction of traverse is clockwise so that the direction of included angle will be anticlockwise that means with (–ve) sign}

Back bearing of line BC $= 130^\circ + 180^\circ = \mathbf{310^\circ}$
Bearing of next line = Bearing of preceding line + Included angle
Fore bearing of line CD = Bearing of line CB + Included angle $\angle$C
$= (180^\circ + 130^\circ) + (-)\ 60^\circ = \mathbf{250^\circ}$
Back bearing of line CD $= 250^\circ - 180^\circ = \mathbf{70^\circ}$
Bearing of next line = Bearing of preceding line + Included angle
Fore bearing of line DA = Bearing of line DC + $\angle D = 70^\circ + 100^\circ = 170^\circ$
Back bearing of line DA $= 170^\circ + 180^\circ = \mathbf{350^\circ}$

Note - (i) If direction of traverse is clockwise then included angle has to be taken in anticlockwise direction or with (–ve) sign.

(ii) If direction of traverse is anticlockwise then included angle has to be taken in clockwise direction or with (+ve) sign.

(iii) If bearing of any line comes more than 360° then for finding out the correct bearing deduct 360° from that amount.

(iv) If bearing of any line comes with negative sign, that means that is not the correct bearing so that for finding out the correct bearing deduct that amount from 360°.

Q.38. What is local attraction ? How will you eliminate the local attraction ?
(R.G.P.V., June 2003, Feb. 2005, June 2005)

Or

Describe the local attraction. ***(R.G.P.V., June 2010)***

Or

What is local attraction ? How it is detected and removed ?
(R.G.P.V., June 2015)

Or

What is local attraction ? And how it is detected at a station ?
(R.G.P.V., Dec. 2015)

Or

Write short note on local attraction. ***(R.G.P.V., Dec. 2017)***

Ans. It is the attraction to the magnetic needle due to surrounding earth magnetic field due to the, iron ores, magnetic rocks, iron electric poles, cables carrying current etc.

Whenever any magnetic needle is leaved freely, it will definitely rest in magnetic north and south, if it is not affected by surrounding earth magnetic field. If there is earth magnetic field surround the magnetic needle, it will deflected from its normal position.

Detection of Local Attraction – The presence of local attraction is detected by observing the fore and back bearings of each line.

If the difference between the fore and back bearings of any line is exactly 180°, that means, that line is free from local attraction.

If the difference between the fore and back bearings of any line not exactly 180° that means line is affected by local attraction.

Method of Elimination of Local Attraction by Included Angles – The following steps are carried out to eliminate the local attraction.

Step-1. Find out the included angles for each station.

Step-2. Apply the check for the sum of included angles. The sum of included angles should be = (2n – 4) 90°. If sum of included angles is not equal to (2n – 4) 90°, then apply the corrections to each angle equally.

Step-3. Find out the line which is free from local attraction, or the diffrence between fore bearing and back bearing is equal to 180°.

Step-4. Starting from the unaffected line, with the help of corrected included angle findout the bearings of another lines.

Method of Elimination of Local Attraction When No Line has Difference 180° in its Fore and Back Bearings –

Sometimes, it may happens in a closed traverse, that no line has a difference of 180° in its fore and back bearings. In that case all the stations are affected from local attraction, then corrected bearings are find out as follows –

Step-1. Calculate the included angles.

Step-2. Check the included angles for the sum (2n– 4) 90° and distribute the error if any, equally to all the angles.

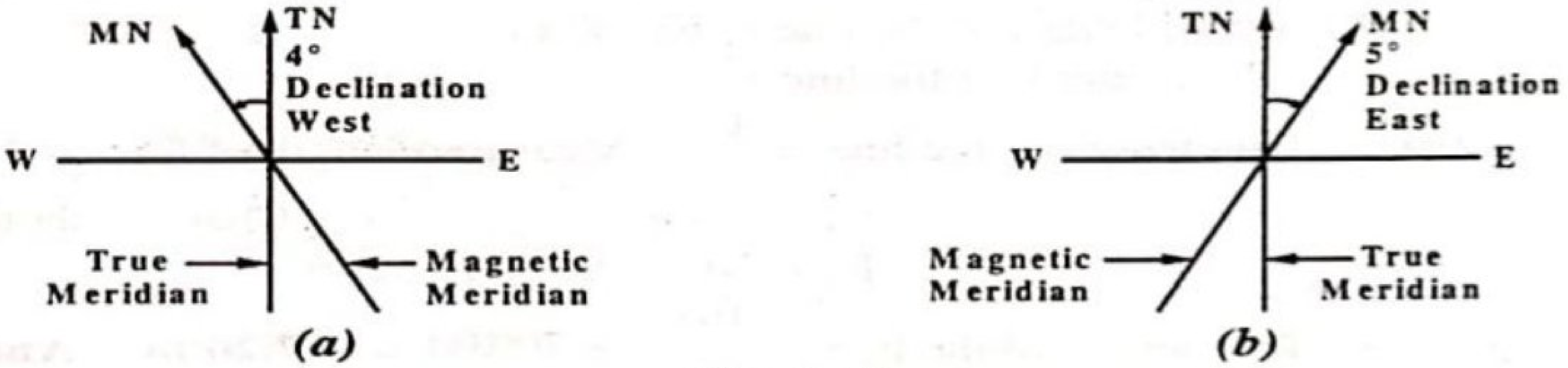
Step-3. Find out the line which having least difference in their fore and back bearings from 180°.

Step-4. Find out the correct bearings of the line by distributing half the error to each of the bearings (Fore bearing & back bearing).

Step-5. Starting from that line having corrected bearing, calculate correct bearings of other lines with the help of corrected included angles.

Q.39. Write short note on magnetic declination.(R.G.P.V., June 2004)

Ans. The magnetic meridian and the true meridian at a place generally do not coincide. The horizontal angle which the magnetic meridian makes with the true meridian is called the magnetic declination or simply declination. If the magnetic north (MN) is to the west of the true north (TN), the declination is said to be west or negative [Fig. 2.49 (a)]. On the other hand, if the magnetic north is to the east of the true north, the declination is said to be east or positive [Fig. 2.49 (b)]. The magnetic declination at a place can be measured in the field by establishing the true meridian by astronomical observations, and then determining the magnetic bearing of the line established along the true meridian.



(a) *(b)*

Fig. 2.49

The declination varies from one place to the other. It also varies at the same place from time to time. The variation of declination at various places is shown by isogonic lines. The isogonic lines are the lines passing through the points on the surface of the earth at which the declination is the same at a given time. As the distribution of earth's magnetism is not uniform, the isogonic lines do not form complete great circles. These lines radiate from the north and south pole regions and follow irregular paths. Isogonic charts are maps showing the isogonic lines of the region. Agonic lines are special isogonic lines which pass through the points having zero declination. In other words, at all points on the agonic lines, the true meridian and the magnetic meridian coincides.

NUMERICAL PROBLEMS

Prob.1. The length of a line was measured with 20 m chain and it worked out to be 580.00 m. After measuring the length, it was found that the chain was 0.06 m too long. What is the true length of the line ?

Sol. Given, length of the chain, $L = 20$ m

Elongation of the chain, $e = 0.06$ m

Measured length of the line $= 580.00$ m

True length of the line $= ?$

$$\text{True length of the line} = \frac{L_1}{L} \times \text{Measured length of line}$$

$$L_1 = L + e \qquad (\because \text{Chain is long})$$

$$L_1 = 20 + 0.06 = 20.06 \text{ m}$$

$$\therefore \quad \text{True length of the line} = \frac{20.06}{20} \times 580.00 = \mathbf{581.74\ m} \quad \textbf{Ans.}$$

Prob.2. The length of a line was measured with 20 m chain and it worked out to be 700.00 m. After measuring the length, it was found that the chain was 0.08 m too short. What is the true length of the line ?

Sol. Given, length of the chain, $L = 20$ m

Shortening of the chain, $e = 0.08$ m

Measured length of the line $= 700.00$ m

True length of the line $= ?$

$$\text{True length of the line} = \frac{L_1}{L} \times \text{Measured length of line}$$

$$L_1 = L - e \qquad (\because \text{Chain is short})$$

$$L_1 = 20 - 0.08 = 19.92 \text{ m}$$

$$\therefore \quad \text{True length of the line} = \frac{19.92}{20} \times 700.00 = \mathbf{697.20\ m} \quad \textbf{Ans.}$$

Prob.3. A 20 m chain was used to measure a distance of 8000 m. After measuring 3500 m. It was found that the chain was 3 cm too long which was correct in the beginning of the work. Again it was found at the end of the work that chain was 6 cm too long. Calculate the correct distance measured.

(R.G.P.V., June 2013)

Sol. Given,

Length of the chain, $L = 20$ m

For the first 3500 m length,

$$\text{Mean elongation of chain} = \frac{0 + 0.03}{2} = 0.015 \text{ m}$$

$$L_1 = 20 + 0.015 = 20.015 \text{ m}$$

True length of line $= \frac{L_1}{L} \times \text{Measured length}$

$$= \frac{20.015}{20} \times 3500 = 3502.625 \text{ m}$$

For the next 4500 m,

Mean elongation of chain $= \frac{0.03 + 0.06}{2} = 0.045$ m

$$L_1 = 20 + 0.045 = 20.045 \text{ m}$$

True length of line $= \frac{L_1}{L} \times \text{Measured length}$

$$= \frac{20.045}{20} \times 4500 = 4510.125 \text{ m}$$

Correct length of measured distance = 3502.625 + 4510.125

= **8012.75 m** **Ans.**

Prob.4. A survey line PQR crosses a river. The points P, Q are on one side and the point R is on other side of the river. The point Q is close to the bank of river. Perpendicular QS 60 metre long is set out at Q. If the bearings of PS and SR are 62° & 332° and the distance PQ is 35 m. Find the distance PR. ***(R.G.P.V., June 2012)***

Sol. Given, PQ = 35 m

QS = 60 m

Bearing of line, SP = 332°

Bearing of line, PS = 62°.

So as, bearing of line,

SP = 180° + 62° = 242°

Hence ∠PSR = 332° – 242° = 90°

In ΔPQS,

∠SPQ = 62° (Given)

∠PQS = 90° (Given)

So as, ∠PSQ = 180° – (90° + 62°) = 28°

If ∠PSR = 90° and ∠PSQ = 28°

Then ∠QSR = 90° – 28° = 62°

Hence,

ΔPQS and ΔQRS are similar triangles

Therefore,

$$\frac{QR}{QS} = \frac{QS}{QP}$$

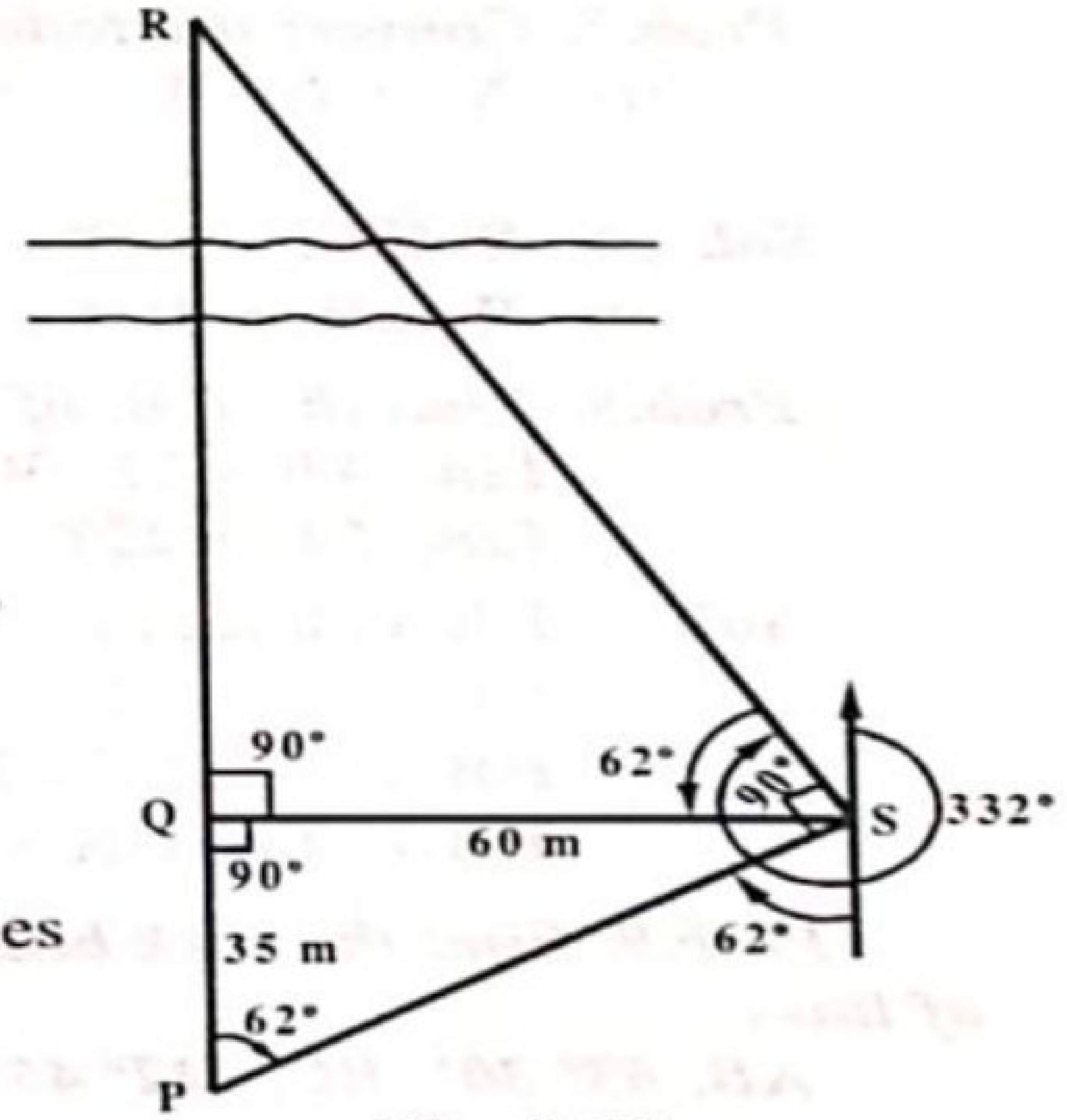


Fig. 2.50

$$QR = \frac{(QS)^2}{QP} = \frac{(60)^2}{35}$$

$$QR = 102.85 \text{ m}$$

Hence,

Distance PR = PQ + QR

= 35 + 102.85 = **137.85 m** Ans

Prob.5. Convert the following whole circle bearings to reduced bearings.

(i) 65° 30' (ii) 140° 20' (iii) 255° 10' (iv) 336° 40' (v) 10° 10

(R.G.P.V., Feb. 2010

Sol. (i) R.B. = 65°30' = **N 65° 30' E** Ans.

(ii) R.B. = 180° – W.C.B. = 180° – 140°20' = **S 39° 40' E** Ans.

(iii) R.B. = W.C.B. – 180° = 255°10' – 180° = **S 75° 10'** Ans.

(iv) R.B. = 360° – W.C.B. = 360° – 336°40' = **N 23° 20' W** Ans.

(v) R.B. = 10° 10' = **N 10° 10' E** Ans.

Prob.6. Convert the following quadrantal bearings to whole circle bearings –

(i) N 15° 20' E, (ii) S 20° 30' E, (iii) S 56° 20' W, (iv) N 45° 30' W

Sol. (i) W.C.B.= R.B. = **15° 20'** Ans.

(ii) W.C.B.= 180° – R.B. = 180° – 20° 30' = **159° 30'** Ans.

(iii) W.C.B.= 180° + R.B. = 180° + 56° 20' = **236° 20'** Ans.

(ii) W.C.B.= 360° – R.B. = 360° – 45° 30' = **314° 30'** Ans.

Prob.7. Convert the following W.C.B. into Q.B. –

(i) N 35°10' W (ii) S 88°30' E.

(R.G.P.V., June 2015)

Sol. (i) W.C.B. = 360° – 35°10' = **324°50'** Ans.

(ii) W.C.B. = 180° – 88°30' = **91°30'** Ans.

Prob.8. Find the F.B. of the following lines from their B.B. –

Line AB = 75° 30', Line CD = 110° 30'

Line EF = 220° 30', Line GH = 280° 30'.

Sol. F.B. of line AB = 75° 30' + 180° = **255° 30'** Ans.

F.B. of line CD = 110° 30' + 180° = **290° 30'** Ans.

F.B. of line EF = 220° 30' – 180° = **40° 30'** Ans.

F.B. of line GH = 280° 30' – 180° = **100° 30'** Ans.

Prob.9. Find the back bearings of the following observed fore bearings of lines –

AB, 63° 30'; BC, 112° 45'; CD, 203° 45'; DE, 320° 30'

(R.G.P.V., Feb. 2010)

Sol. B.B. of line AB = F.B. + 180° = 63° 30' + 180 = **243° 30'** **Ans.**

B.B. of line BC = F.B. + 180° = 112° 45' + 180° = **292° 45'** **Ans.**

B.B. of line CD = F.B. – 180° = 203° 45' – 180° = **23° 45'** **Ans.**

B.B. of line DE = F.B. – 180° = 320° 30' – 180 = **140° 30'** **Ans.**

Prob.10. Following bearings were observed during a compass survey of a closed traverse ABCD in a clockwise direction –

Line	*F.B.*
AB	*38°*
BC	*72°*
CD	*197°*
DA	*279°*

Find the included angles and apply the check. (R.G.P.V., Sept. 2009)

Sol.

Included angle = Bearing of next line – Bearing of preceding line

∠A = Bearing of line AB – Bearing of line AD

= 38° – (279° – 180°)

(∵ Bearing of line AD = Bearing of line DA – 180°)

= 38° – 99° = **61° (Anticlockwise)** **Ans.**

∠B = Bearing of line BC – Bearing of line BA

= 72° – (38° + 180°)

(∵ Bearing of line BA = Bearing of line AB + 180°)

= 72° – 218° = **146° (Anticlockwise)** **Ans.**

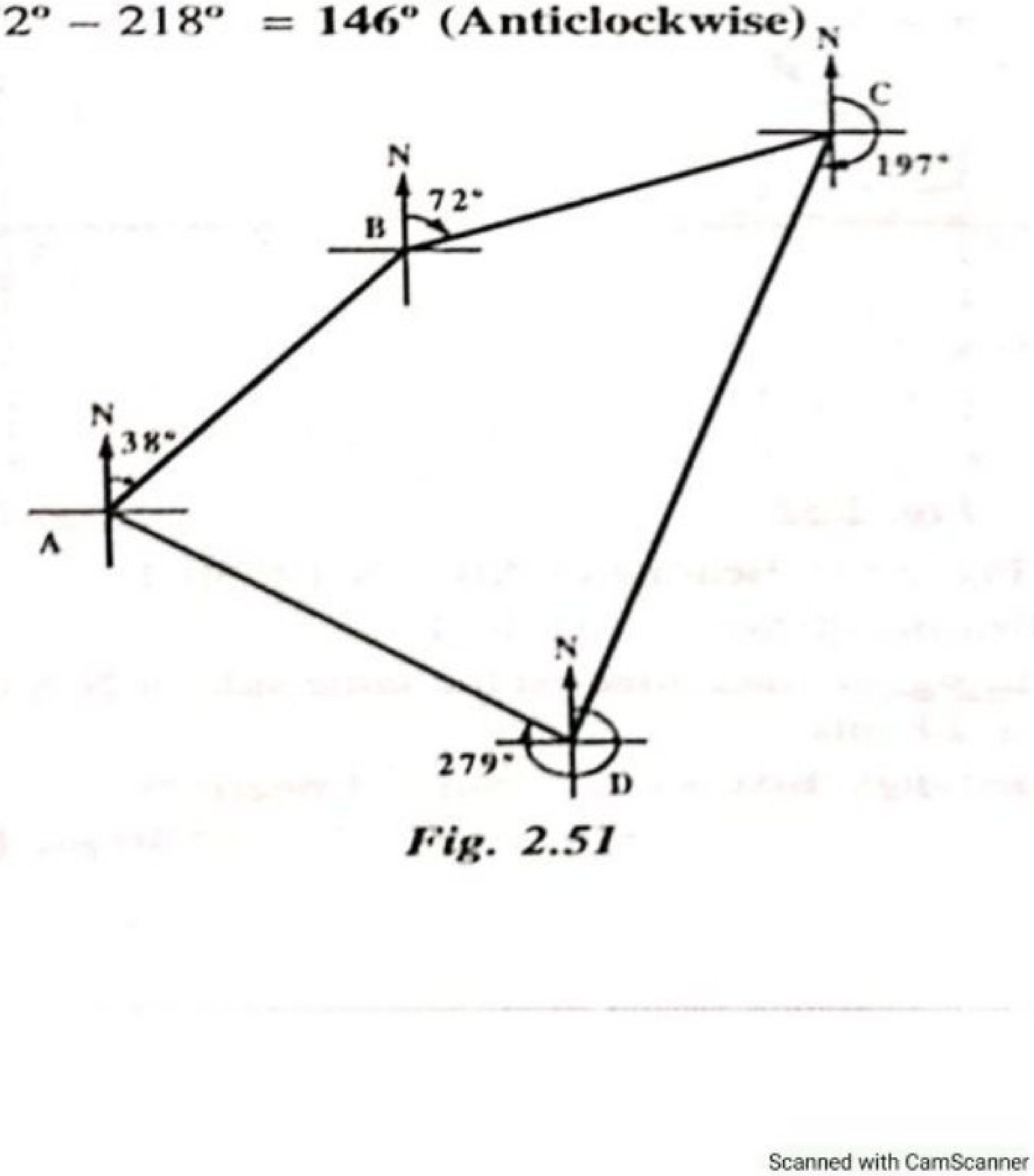


Fig. 2.51

$\angle C$ = Bearing of line CD – Bearing of line CB

$= 197° - (72° + 180°)$

(∵ Bearing of line CB = Bearing of line BC + 180°)

$= 197° - 252° = $ **55° (Anticlockwise)** **Ans.**

$\angle D$ = Bearing of line DA – Bearing of line DC

$= 279° - (197° - 180°)$

(∵ Bearing of line DC = Bearing of line CD – 180°)

$= 279° - 17° = 262°$ (Clockwise) (Exterior angle)

Hence interior angle $= 360° - 262° =$ **98° (Anticlockwise)** **Ans.**

Check $= \angle A + \angle B + \angle C + \angle D$

$= 61° + 146° + 55° + 98° = 360°$ **Hence O.K.**

Prob.11. Find the included angle between the lines AB and AC, if their reduced bearings are –

- *(i) AB, N 40° 10′ E; AC, N 89° 45′ E*
- *(ii) AB, N 10° 50′ E; AC, S 40° 40′ E*
- *(iii) AB, S 35° 45′ W; AC, N 45° 20′ E*
- *(iv) AB, N 30° 25′ E; AC, N 30° 25′ W.*

Sol. (i) (Fig. 2.52). Bearing of AB = N 40° 10′ E

Bearing of AC = N 89° 45′ E

As the bearings are measured on the same side of the north meridian, and both lie in the NE quadrant.

∴ Included angle ABC = Difference in the bearings

$= 89° 45' - 40° 10' =$ **49° 35′.** **Ans.**

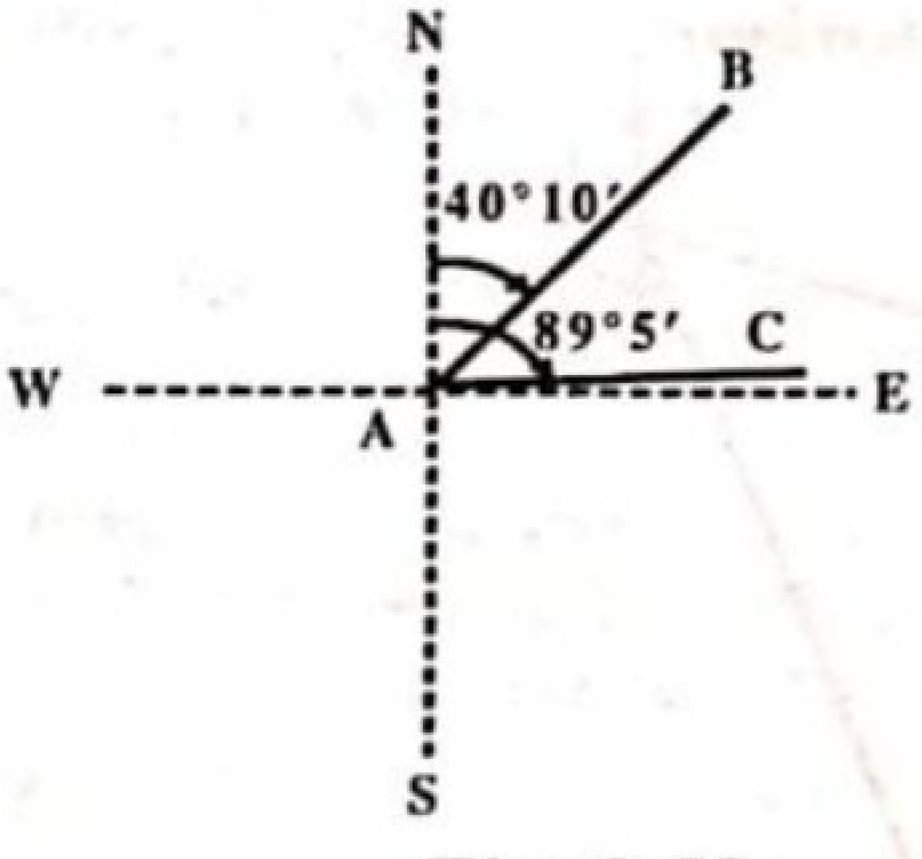


Fig. 2.52

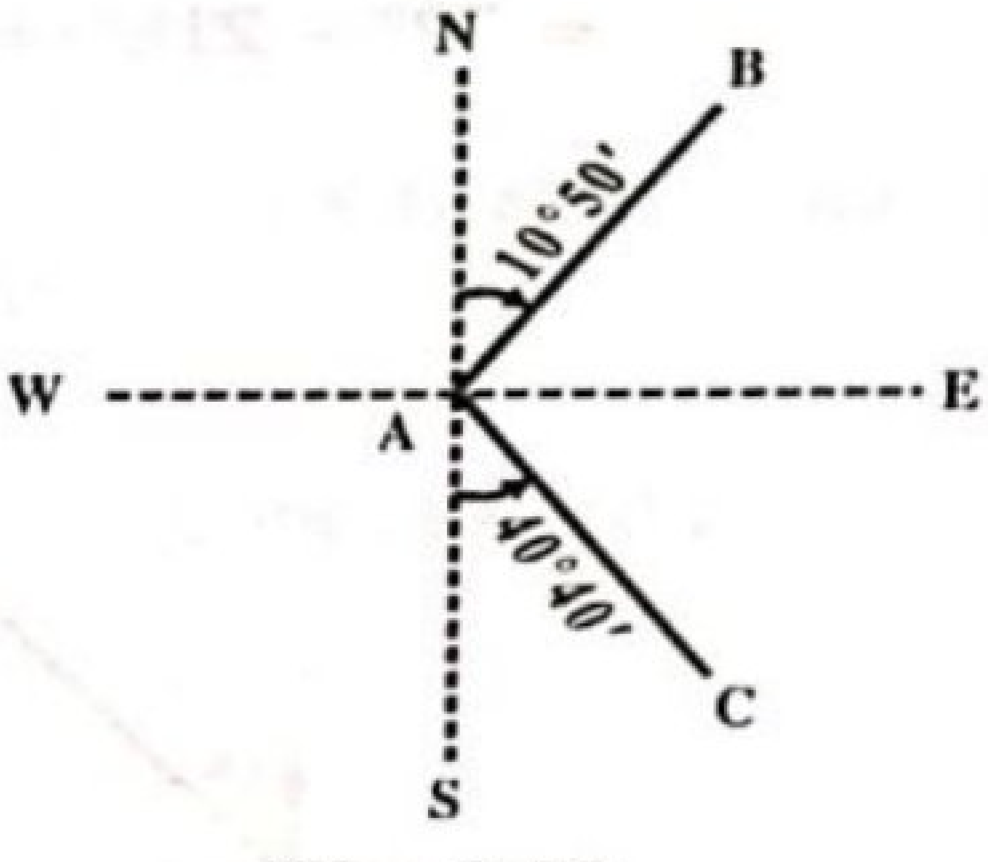


Fig. 2.53

(ii) (Fig. 2.53). Bearing of AB = N 10° 50′ E

Bearing of AC = S 40° 40′ E

As the bearings are measured on the same side of N-S meridian, but both lie in adjacent quadrants.

∴ Included angle BAC = 180° – Sum of bearings

$= 180° - (10° 50' + 40° 40') =$ **128° 30′** **Ans.**

(iii) (Fig. 2.54). Bearing of AB = S 35° 45' W

Bearing of AC = N 45° 20' E

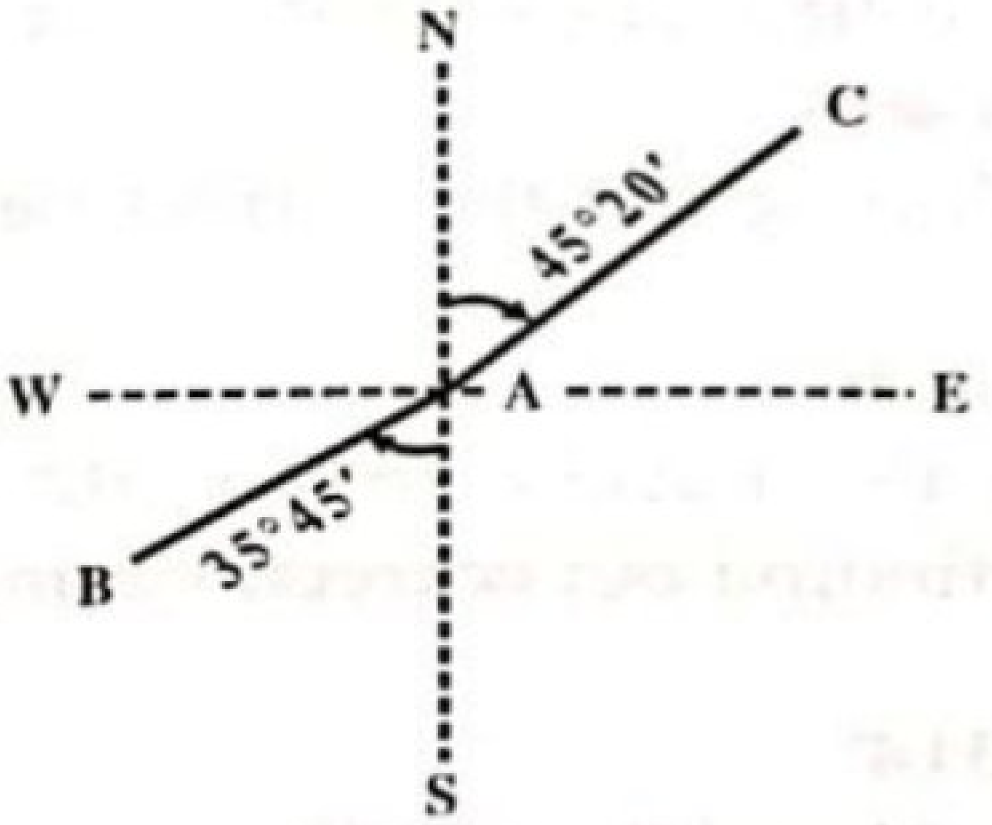


Fig. 2.54

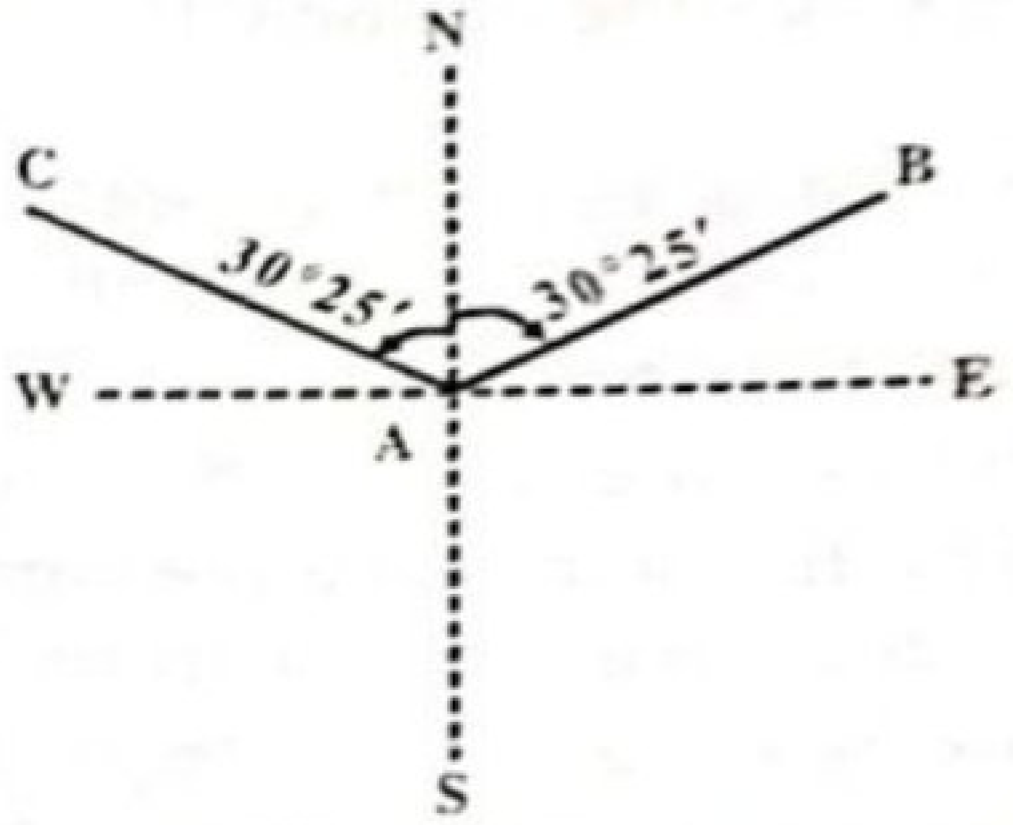


Fig. 2.55

As the bearings are measured on the opposite sides of the meridian and they do not lie in adjoining quadrants, the included angle ABC

= 180° – (Difference in bearings)

= 180° – (45° 20' – 35° 45') = **170°25'** **Ans.**

(iv) (Fig. 2.55). Bearing of AB = N 30° 25' E

Bearing of AC = N 30° 25' W

As the bearings are measured from opposite side of common meridian and they lie in adjacent quadrants,

The included angle BAC = Sum of the bearings

= 30° 25' + 30° 25' = **60° 50'** **Ans.**

Prob.12. In a closed traverse the following included angles were measured by means of a compass – A = 132°, B = 116°, C= 106°, D = 92°, E = 99°50'. If F.B. of the line AB is 88°. Find bearings of all remaining sides.

(R.G.P.V., April 2009)

Sol. Fore bearing of line AB = 88° (Given)

Back bearing of line AB = 88° + 180°

= **268°** **Ans.**

Fore bearing of line BC

= Bearing of line BA + ∠B

= 268° + (– 116°) = **152°** **Ans.**

(As direction of traverse is clockwise, so that the direction of included angle will be anticlockwise with –ve sign)

Back bearing of line BC

= Fore bearing of line BC + 180°

= 152° + 180° = **332°** **Ans.**

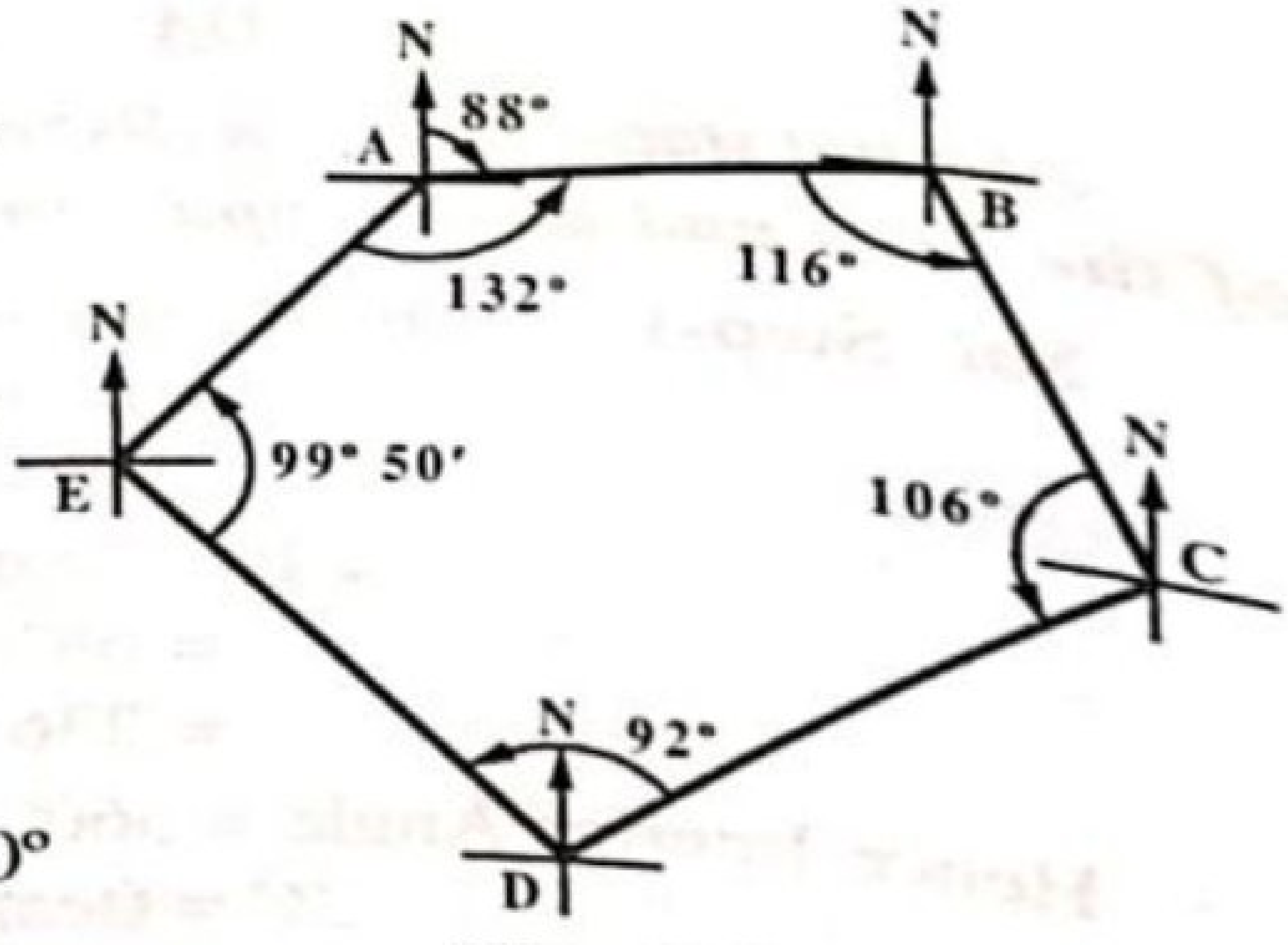


Fig. 2.56

Fore bearing of line CD = Bearing of line CB + $\angle C$

$= 332° + (-106°) = \mathbf{226°}$ An

Back bearing of line CD = Fore bearing of line CD + 180°

$= 226° + 180° = 406°$

(Which is more than 360°, so that for finding out the correct bearing line CD, deduct 360° from that amount)

$\therefore$ Back bearing of line CD $= 406° - 360° = \mathbf{46°}$ An

Fore bearing of line DE = Bearing of line DC + $\angle D = 46° + (-92°) = -4$

(Which is with negative sign, so that for finding out correct bearing of li DE, deduct that amount from 360°)

$\therefore$ Fore bearing of line DE $= 360° - 46° = \mathbf{314°}$ An

Back bearing of line DE = Fore bearing of line DE − 180°

$= 314° - 180° = \mathbf{134°}$ An

Fore bearing of line EA = Bearing of line ED + $\angle E$

$= 134° + (-99°50') = \mathbf{34°10'}$ An

Back bearing of line EA = Fore bearing of line EA + 180°

$= 34°10' + 180° = \mathbf{214°10'}$ Ans

Line	*Fore Bearing*	*Back Bearing*
AB	88°	268°
BC	152°	332°
CD	226°	46°
DE	314°	134°
EA	34°10'	214°10'

Prob.13. The following bearing were taken in running a compass traverse-

Line	***F.B.***	***B.B.***
AB	***124°30'***	***304°30'***
BC	***68°15'***	***246°00'***
CD	***310°30'***	***135°15'***
DA	***200°15'***	***17°45'***

At what stations do you suspect local attraction ? Find the correct bearin of the lines and also compute the included angles. (R.G.P.V., Dec. 2005

***Sol.* Step-1. Calculation of Included Angles**

$\angle A$ = Bearing of line AB − Bearing of line AD

$= 124° 30' - 17° 15' = 107° 15'$ (clockwise (+ve)

$\angle B$ = Bearing of line BC − Bearing of line BA

$= 68° 15' - 304° 30'$

$= 236° 15'$ (Anticlockwise) (−ve) (Exterior angle

Hence Interior Angle $= 360° - 236° 15' = 123° 45'$ (clockwise) (+ve)

$\angle C$ = Bearing of line CD − Bearing of line CB

$= 310° 30' - 246° 00' = 64° 30'$ (clockwise) (+ve

∠D = Bearing of line DA – Bearing fo line DC
= 200° 15' – 135° 15' = 65° 00' (clockwise) (+ve)

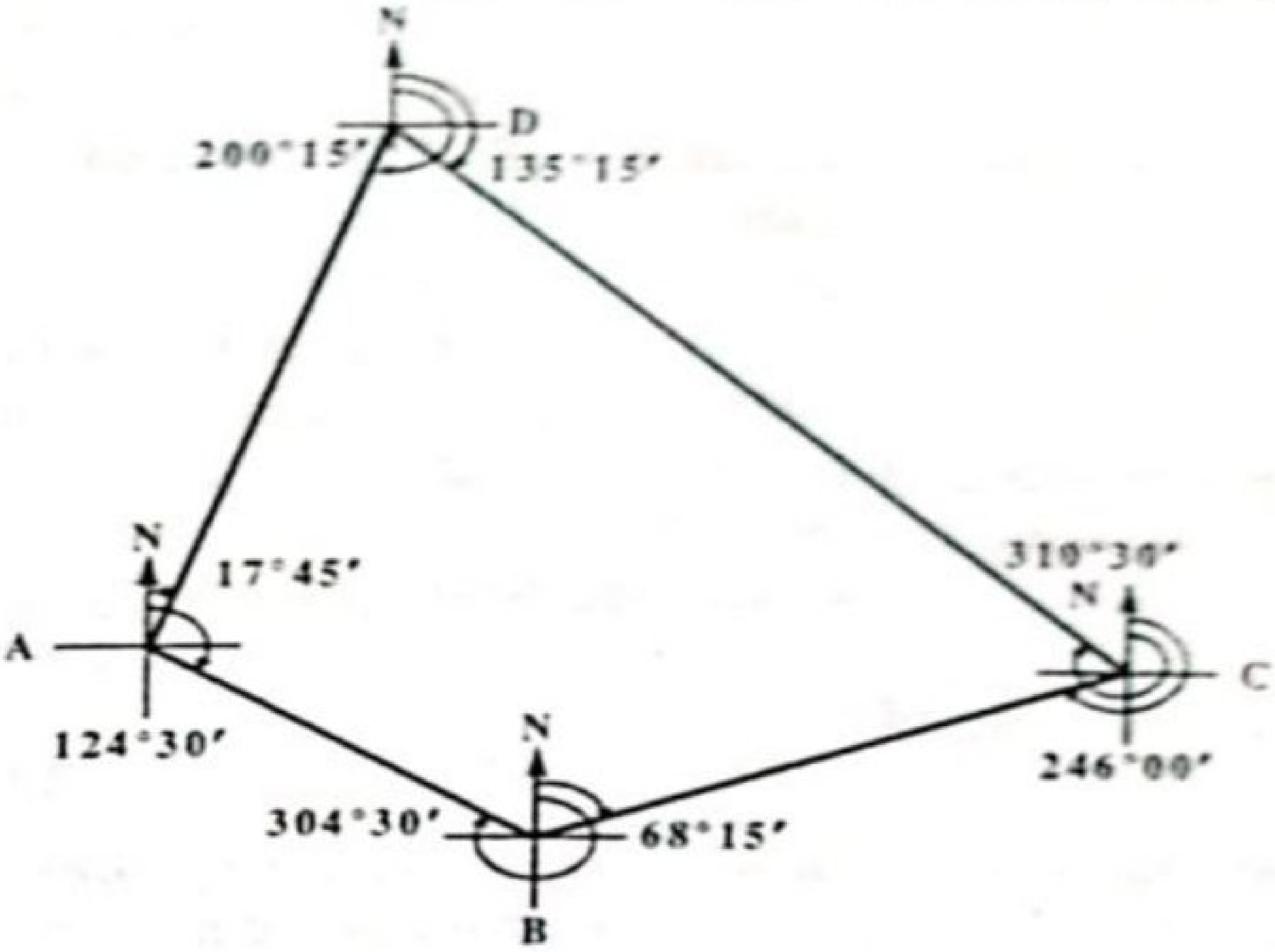


Fig. 2.57

Step-2. Check for Included Angles

The sum of Included angles should be equal to (2n – 4) 90° = (2 × 4 – 4) 90° = 360°

∠A + ∠B + ∠C + ∠D = 107° 15' + 123° 45' + 64° 30' + 65° 00' = 360° 30'

The sum of Included angles is 360° 30'

Therefore there is an error of (360° 30' – 360°) = 30'

This may be equally distributed among the angles and the same may be corrected

The correction for each angle $\frac{30'}{4} = 7'30''$

Therefore, the corrected angles of the traverse are –

∠A = 107° 15' – 7' 30" = 107° 7' 30"
∠B = 123° 45' – 7' 30" = 123° 37' 30"
∠C = 64° 30' – 7' 30" = 64° 22' 30"
∠D = 65° 00' – 7' 30" = 64° 52' 30"

Step-3. Finding out the Line which is Free from Local Attraction –

On examination, we find that fore and back bearings of line AB are differ xactly by 180°. Hence stations A and B are free from local attraction. That neans bearings of line CD are the corrected bearings.

Step-4 Calculation of Bearings –

Corrected fore bearing of line AB = **124° 30'** Ans.
Corrected back bearing of line AB = **304° 30'** Ans.

Corrected fore bearing of line BC

= Corrected bearing of line BA + Corrected ∠B

= 304° 30' + 123° 37' 30" = 428° 7' 30"

= 428° 7' 30" – 360° = **68° 7' 30"** **Ans.**

Corrected back bearing of line BC = 68° 7' 30" + 180°

= **248° 7' 30"** **Ans.**

Corrected fore bearing of line CD

= Corrected bearing of CB + Corrected ∠C

= 248° 7' 30" + 64° 22' 30" = **312° 30'** **Ans.**

Corrected back bearing of line CD = 312° 30' – 180° = **132° 30'** **Ans.**

Corrected fore bearing of line DA

= Corrected bearing of DC = ∠D

= 132° 30' + 64° 52' 30" = **197° 22' 30"** **Ans.**

Corrected back bearing of line DA

= 197° 22' 30" – 180° = **17° 22' 30"** **Ans.**

Prob.14. Find out which stations are affected by local attraction and find out the correct bearings of the lines of a closed traverse ABCDEA.

Line	*Fore Bearings*	*Back Bearings*
AB	*191°30'*	*13°00'*
BC	*69°30'*	*246°30'*
CD	*32°15'*	*210°30'*
DE	*262°45'*	*80°45'*
EA	*230°15'*	*53°00'*

Sol. **Step-1.Calculation of Included Angles**

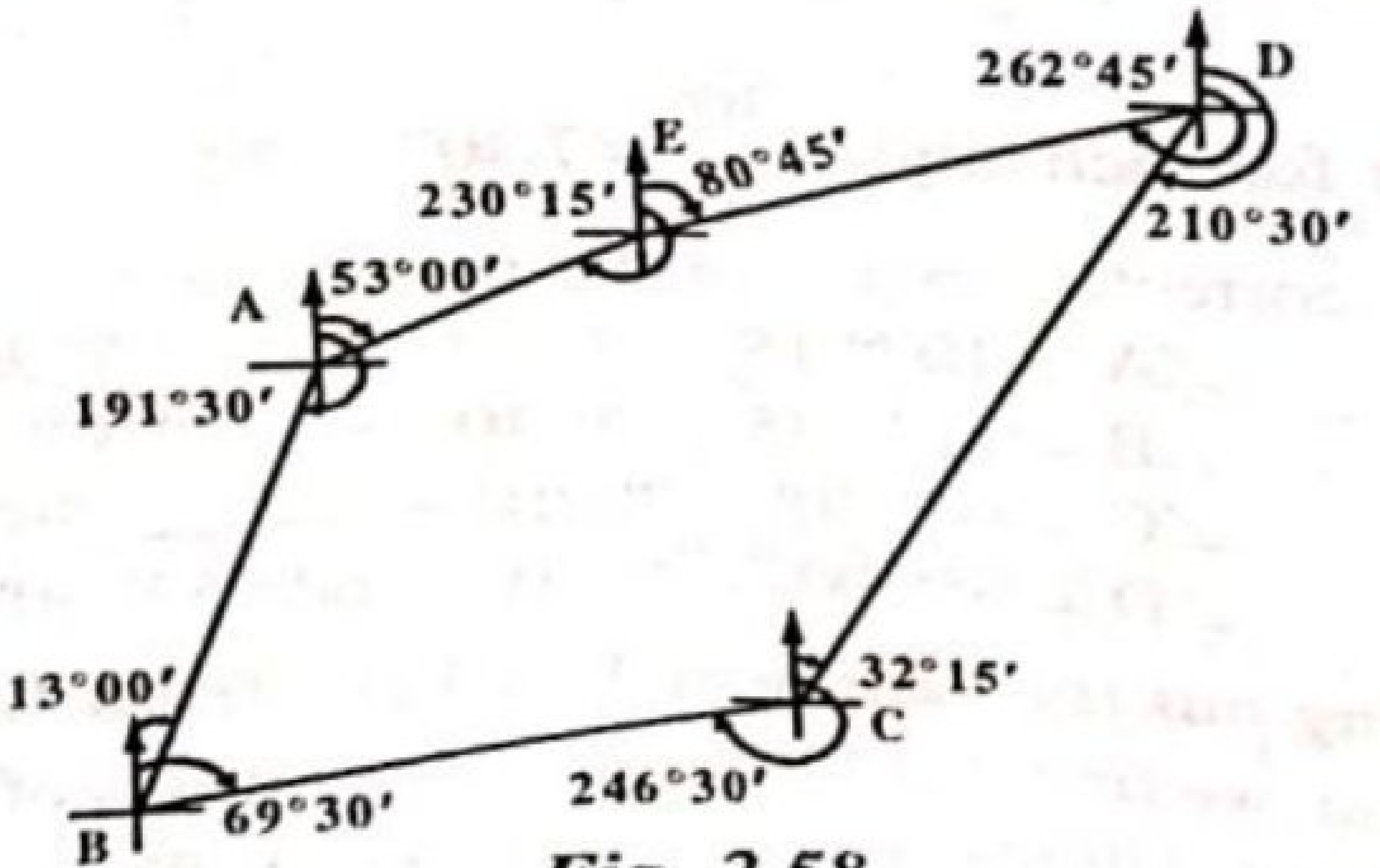


Fig. 2.58

∠A = Bearing of line AB – Bearing of line AE

= 191° 30'– 53° 00' = 138° 30' (+ve) (clockwise)

∠B = Bearing of line BC – Bearing of line BA

= 69° 30'– 13° 00' = 56° 30' (+ve) (clockwise)

∠ C = Bearing of line CD – Bearing of line CB
= 32° 15' – 246° 30' = 214° 15' (–ve)

(Hence sign of angle is changed and comes –ve so that)

Corrected angle ∠ C = 360° – 214° 15'= 145° 45'

∠ D = Bearing of line DE – Bearing of line DC
= 262° 45'– 210° 30' = 52° 15'

∠ E = Bearing of line EA – Bearing of line ED
= 230° 15' – 80° 45' = 149° 30'

Step-2. Check For Included Angles

The sum of included angles should be equal to (2n – 4) 90°
= (2 × 5 – 4) 90° = 540°

The required sum of the included angles
= ∠ A + ∠ B + ∠ C + ∠ D +∠ E
= 138° 30'+ 56° 30'+ 145° 45' + 52° 15' + 149° 30' = 542° 30'

Total error = 542° 30' – 540° = 2° 30'

Correction for each angle = 2°30'/5 = 30'

Correction for each angle will be (–ve) because of sum of the angles is more than 540°.

Corrected angle ∠ A = 138° 30' – 30' = 138° 00'
Corrected angle ∠ B = 56° 30' – 30' = 56° 00'
Corrected angle ∠ C = 145° 45' – 30' = 145° 15'
Corrected angle ∠ D = 52° 15' – 30' = 51° 45'
Corrected angle ∠ E = 149° 30' – 30' = 149° 00'

Note – (i) If required sum of the angles is more than the theoretical sum then correction will be negative (–ve).

(ii) If required sum of the angles is less than the theoretical sum then correction will be positive (+ve).

Step-3. Find out the Line Which Having Least Difference in Their Fore and Back Bearings

Bearing of line AB – Bearing of line BA = 191° 30' – 13° 00' = 178° 30'
Bearing of line BC – Bearing of line CB = 69° 30' – 246° 30' = 177° 00'
Bearing of line CD – Bearing of line DC = 32° 15' – 210° 30' = 178° 15'
Bearing of line DE – Bearing of line ED = 262° 45' – 80° 45' = 182° 00'
Bearing of line EA – Bearing of line AE = 230° 15' – 53° 00' = 177° 15'

From above, it is seen that the fore and back bearings of the side AB differ the least from 180°.

Step-4. Find out the Correct Bearing of Line

∴ The difference in bearings or error = 180° – 178° 30' = 1° 30'

∴ Correct fore bearing of line AB = Fore bearing of line AB + 1/2 error
= 191° 30' + 1°30'/2 = 192° 15'

Correct back bearing of line AB = 13°00' – 1°30'/2 = 12°15'

Note – 1. Condition (I) – When fore bearing of any line is greater than 18

(a) If difference in bearings or error is positive (+ve), the correction will be positive (+ve) in fore bearing and (–ve) in back bearing that line.

(b) If difference in bearings or error is negative (–ve) the correction will be negative (–ve) in fore bearing and (+ve) in back bearing that line.

2. Condition (II)

When fore bearing of any line is less than 180° –

(a) If difference in bearings or error is positive (+ve), the correction will be (–ve) negative in fore bearing and (+ve) positive in bac bearing of that line.

(b) If difference in bearings or error is (–ve) negative, the correction will be (+ve) positive in fore bearing and (–ve) negative in bac bearing of that line.

Step-5. Calculations of Bearings

Corrected fore bearing of line AB = **192°15′** Ans

Corrected back bearing of line AB = **12°15′** Ans

Corrected fore bearing of line BC = Corrected Bearing of line BA + ∠

= 12° 15′+ 56° 00′ = **68°15′** Ans

[As the direction of traverse is anticlockwise so that included angle wi be clockwise (+ve)]

Corrected back bearing of line BC = Corrected fore bearing of line BC + 18

= 68° 15′ + 180° = **248°15′** Ans

Corrected fore bearing of line CD = Corrected bearing of line CB + ∠

= 248° 15′+ 145° 15′ = 393° 30′

(As it is greater than 360° so that)

Corrected fore bearing of line CD = 393° 30′ – 360° = **33° 30′** Ans

Corrected back bearing of line CD = Fore bearing of line CD + 180°

= 33° 30′+ 180° 00′ = **213° 30′** Ans

Corrected fore bearing of line DE = Bearing of line DC + ∠D

= 213° 30′+ 51° 45′ = **265° 15′** Ans

Corrected back bearing of line DE = Fore bearing of line DE – 180°

= 265° 15′ – 180° = **85° 15′** Ans

Corrected fore bearing of line EA = Bearing of line ED + ∠E

= 85° 15′+ 149° 00′ = **234° 15′** Ans

Corrected back bearing of line EA = Fore bearing of line EA – 180°

= 234° 15′ – 180° = **54° 15′** Ans

Results – Corrected bearing of lines are as follows –

Line	*Fore Bearing*	*Back Bearing*
AB	192° 15'	12° 15'
BC	68° 15'	248° 15'
CD	33° 30'	213° 30'
DE	265° 15'	85° 15'
EA	234° 15'	54° 15'

Prob.15. Find the true bearings of the line AB if the magnetic bearings and declinations are as follows –

(i) Magnetic bearing = 212°34' and declination = 2°12' W,

(ii) Magnetic bearing = S 45°12' E and declination = 3°17' E, and

(iii) Magnetic bearing = 312°45' and declination = 8°44' E.

Sol. (i) True bearing = Magnetic bearing – Declination (west)
= 212°34' – 2°12' = **210°22'** **Ans.**

(ii) True bearing = Magnetic bearing + Declination (east)
= 134°48' + 3°17' = **138°05'** **Ans.**

(iii) True bearing = Magnetic bearing + Declination (east)
= 312°45' + 8°44' = **321°29'** **Ans.**

Prob.16. Find the magnetic bearing of the line AB from the following true bearing and declinations –

(i) True bearing = 48°12' and declination = 4°08' E, and

(ii) True bearing = S 10°12' W and declination = 2°04' W

Sol. (i) True bearing = Magnetic bearing + Declination (east)

∴ Magnetic bearing = True bearing – Declination (east)
= 48°12' – 4°08' = **44°04'** **Ans.**

(ii) True bearing = Magnetic bearing – Declination (west)

∴ Magnetic bearing = True bearing + Declination (west)
= 190°12' + 2°04' = **192°16'** **Ans.**

LEVELS

Q.40. Explain the term levelling. ***(R.G.P.V., June/July 2006)***

Ans. Levelling is a method of surveying to determine the relative elevations of the points on the surface of the earth. Following are the objects of the levelling –

(i) To establish points at desired elevations with respect to the given datum.

(ii) To determine the elevations of given points with respect to the given

Levelling deals with the measurements in a vertical plane. Levelling is ver much useful in the initial stages of the design of the project as well as durin the execution of the project. Levelling is an important method of surveying f many engineering works and construction projects. Levelling is very muc useful for the purpose of design of railways, highways, canals, dams, sewe ete. Levelling is required for estimating the reservoir capacities, for locatin the gradient lines and for the layout of the construction projects, for locatin the excavations levels, and for the control of various elevations in buildin dams, bridges etc. The drainage characteristics of the area can be obtained b levelling.

Q.41. What is the principle of levelling ?

Ans. When the levelling instrument has been properly levelled, the bubb tube axis and the line of sight are horizontal and the vertical axis of the instrume is truly vertical. When the telescope of the instrument is rotated, the line sight remains in the horizontal plane. Because for small distances, there is n much difference between an level line and a horizontal line.

In actual practice, level of the line of sight is determined by set up levelling instrument at a convenient position and reading of staff is take which is kept at a point of known elevation.

Q.42. Write down the levelling instruments.

Ans. In the process of levelling following two important instruments a used –

(i) Level
(ii) Levelling staff.

(i) Level – The instrument which is used for levelling and purpo of which is to provide a horizontal line of sight is called as level. It contai following essential parts –

(a)Telescope (b) Level tube or bubble tube (c) Levelling hea

(ii) Levelling Staff – Levelling Staff is a straight rectangular ro made from timber or metal. It is graduated with the foot of staff representin zero reading. It is kept vertical at the point whose elevation is either known to be determind. The purpose of levelling staff is to determine the amount b which the station is below or above the line of sight. The levelling staves of m or 4 m lengths are generally used in practice. Each metre is divided into 20 divisions. The thickness of each division is 5 mm. The division are painte alternatively black and white.The graduations are marked inverted so that whe viewed through a telescope they appear erect. The metre numerals are general written on the right in red but the decimetre numerals are in black and to th left.

Levelling staff may be divided into two classes –

(a) Self reading staff –

(1) Solid staff (2) Folding staff (3) Telescopic staff.

(b) Target staff.

Q.43. What are the different types of levels ?

Or

Describe in brief level equipments along with their uses.

(R.G.P.V., Dec. 2010)

Ans. There are following types of levels –

(i) Dumpy level (ii) Wye level (iii) Reversible level (iv) Tilting level.

(i) Dumpy Level – Fig. 2.59 shows the sketch of a dumpy level. It is very simple, stable and easy to use. It consist of telescope, which is fixed with the supports and hence, it is not possible to rotate it about its own axis. A long bubble tube is attached to the top of the telescope. The levelling head generally consists of two parallel plates having three or four foot screws. The upper plate is known as tribarch and the lower plate is known as trivet which is screwed on the tripod before setting up.

The telescope can be rotated in the horizontal plane about its vertical axis. The telescope of the dumpy level is generally of the internal focussing type. Dumpy level required greater stability of adjustments. However, it requires more time for carrying out its permanent adjustments, once it gets out of the permanent adjustment.

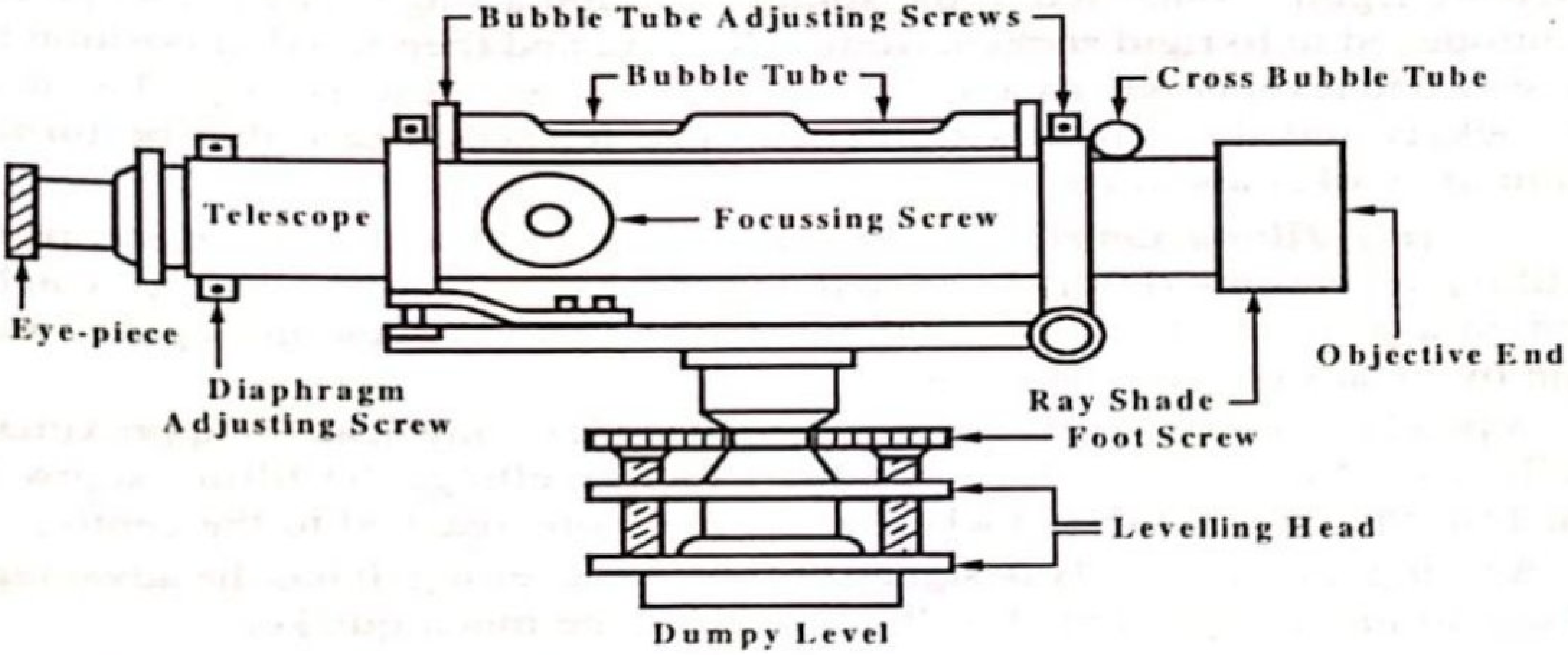


Fig. 2.59 Dumpy Level

(ii) Wye or Y-Level – Fig. 2.60 shows the details of a wye level. It consists of various loose parts hence,it requires careful handling. The telescope is rest on the supports having the shape of letter Y hence, it is called as Y-level. The Y supports are two clip which may be raised to enable the telescope to be rotated about its longitudinal axis, and also to be removed and turned end to end. The adjustments soon get disturbed due to loose supports and hence, it is necessary to check them quickly.

The bubble tube may be attached either to the telescope or to the stage carrying the wyes.

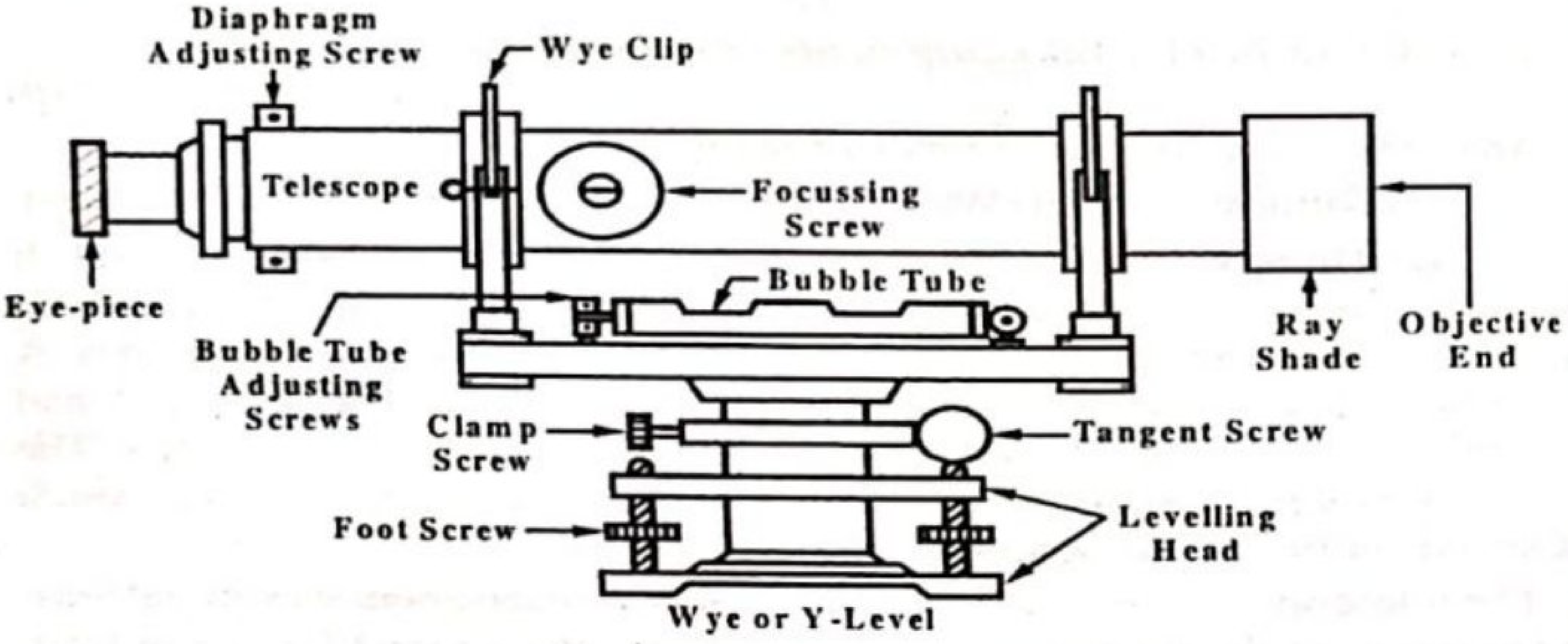


Fig. 2.60 Wye or Y-Level

(iii) Reversible Level – It combines the features of both the dumpy level and the wye level. In this the telescope is supported by two rigid sockets, which are rigidly connected to the spindle through a stage. The telescope can be introduced in to rigid sockets from either end and then fixed in position by a screw. The level is acts as a dumpy level when the telescope is pushed in to the sockets and the screw is tightened. The telescope can also be turned within the socket about the longitudinal axis.

(iv) Tilting Level – It is much precise and quick. The telescope of the tilting level is not rigidly fixed to the vertical spindle. The telescope can be tilted on a pivot about a horizontal axis in the vertical plane through a small angle by means of a tilting screw.

A pond level is fixed to the upper plate of the levelling head for approximate levelling by foot screws. Now for the exact levelling, the tilting screw is turned till the bubble tube attached to the telescope reached to the centre.

A tilting level is mainly designed for precise levelling. It has the advantage that due to the tilting screw, levelling can be done much quicker.

Q.44. Write down the classification of levelling. Describe any one type of levelling.

Ans. The levelling can broadly be divided into the following two categories –

(i) Direct levelling (ii) Indirect levelling.

Direct Levelling – This method is also known as spirit levelling and it is the most commonly used method of levelling. The method employs spirit level and telescope to measure vertical distances on the levelling staff placed on various points. Various forms of direct levelling are as follows –

(i) Simple levelling
(ii) Differential levelling
(iii) Reciprocal levelling
(iv) Profile levelling
(v) Cross-sectioning
(vi) Precise levelling
(vii) Check levelling
(viii) Fly levelling.

(i) Simple Levelling – It is used to find out the difference in elevations of two points which are visible from a single position of the level. In fig. 2.61, let P be the point of known elevation, say 100 and let it be required to find out the elevation of point Q. The instrument is set up roughly midway between the points P and Q and the temporary adjustments are performed. The telescope is directed towards the point P and then at Q. The readings are noted. The elevation of Q is worked out as follows –

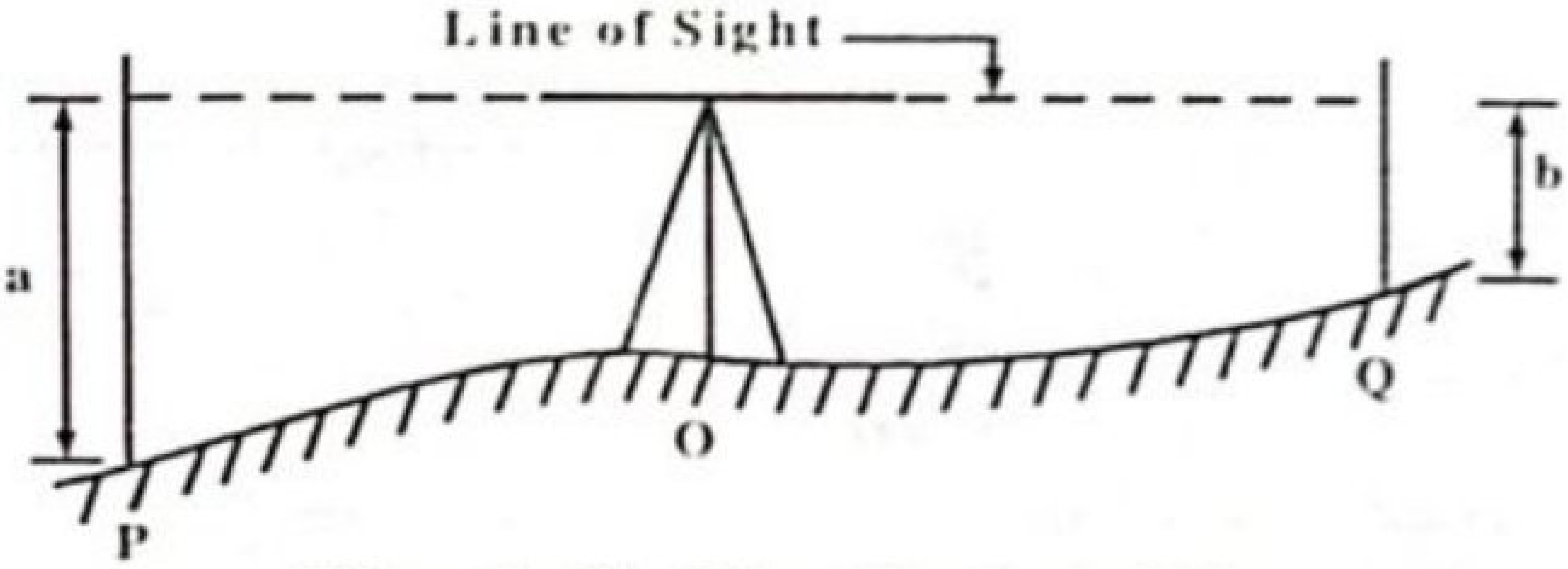


Fig. 2.61 Simple Levelling

Height of instrument at O = 100 + a

Elevation of point Q = (100 + a) – b

Following points should be noted –

(a) If the point is situated at a lower level, the staff reading will be more and if it is situated at a higher level, the staff reading will be less.

(b) It should be seen that the bubble remains in its central position, when the readings are taken.

(ii) Differential Levelling – The process of differential levelling, also known as compound levelling or continuous levelling, is resorted to under the following circumstances –

(a) The points P and Q are situated far away from each other.

(b) The difference in elevations of points P and Q is too great.

(c) There is presence of obstacles between points P and Q.

In this process, the change points or C.P. are selected as required. As shown in fig. 2.62, the level is set up at O_1 and with the bubble in central position, the staff readings are taken for points P and first C.P. The process is repeated at points O_2 and O_3 till the point Q is reached. The difference in level of P and Q can then be worked out by simple calculations as follows –

$$\text{Difference} = (b_1 - a) + (c_1 - b_2) + (b - c_2).$$

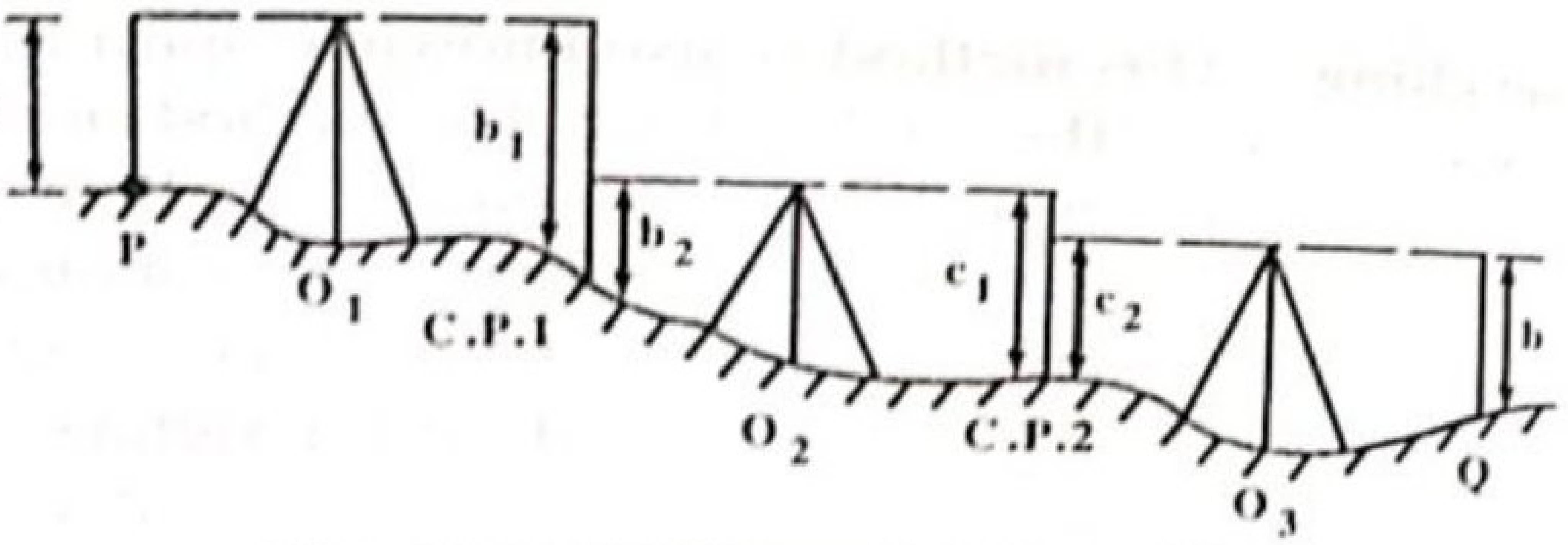


Fig. 2.62 Differential Levelling

If the difference works out to be positive, point Q is higher than point P and if it works out to be negative, point Q is lower than point P. It may be noted that the readings at a change point are taken twice i.e. once before and the next after the instrument is shifted. The location and situation of change point should be carried out carefully. The positions O_1, O_2 and O_3 of the instrument should be selected in such a way that the level lies roughly midway between the points to be read.

Imp *(iii) Reciprocal Levelling* – Refer Q.45.

(iv) Profile Levelling – The process of levelling carried out along a given line to determine the elevations of points at known distances is known as the profile levelling or the longitudinal sectioning. This process is useful for getting the data for the design of engineering structures such as road, railway, canal, sewer, water main, etc.

The instrument is set up at the convenient point and reading is taken on a bench mark. The staff is then held at various points along the line and staff readings are taken. The distances of the points are also noted. With usual precautions, the levelling process is completed. If required, change points may be established for smooth operation of the levelling process.

The plotting of readings is then carried out, as shown in fig. 2.63. The horizontal distances are marked along the horizontal axis and vertical distances with suitable datum are marked on vertical lines drawn at each point. The horizontal scale and vertical scale are

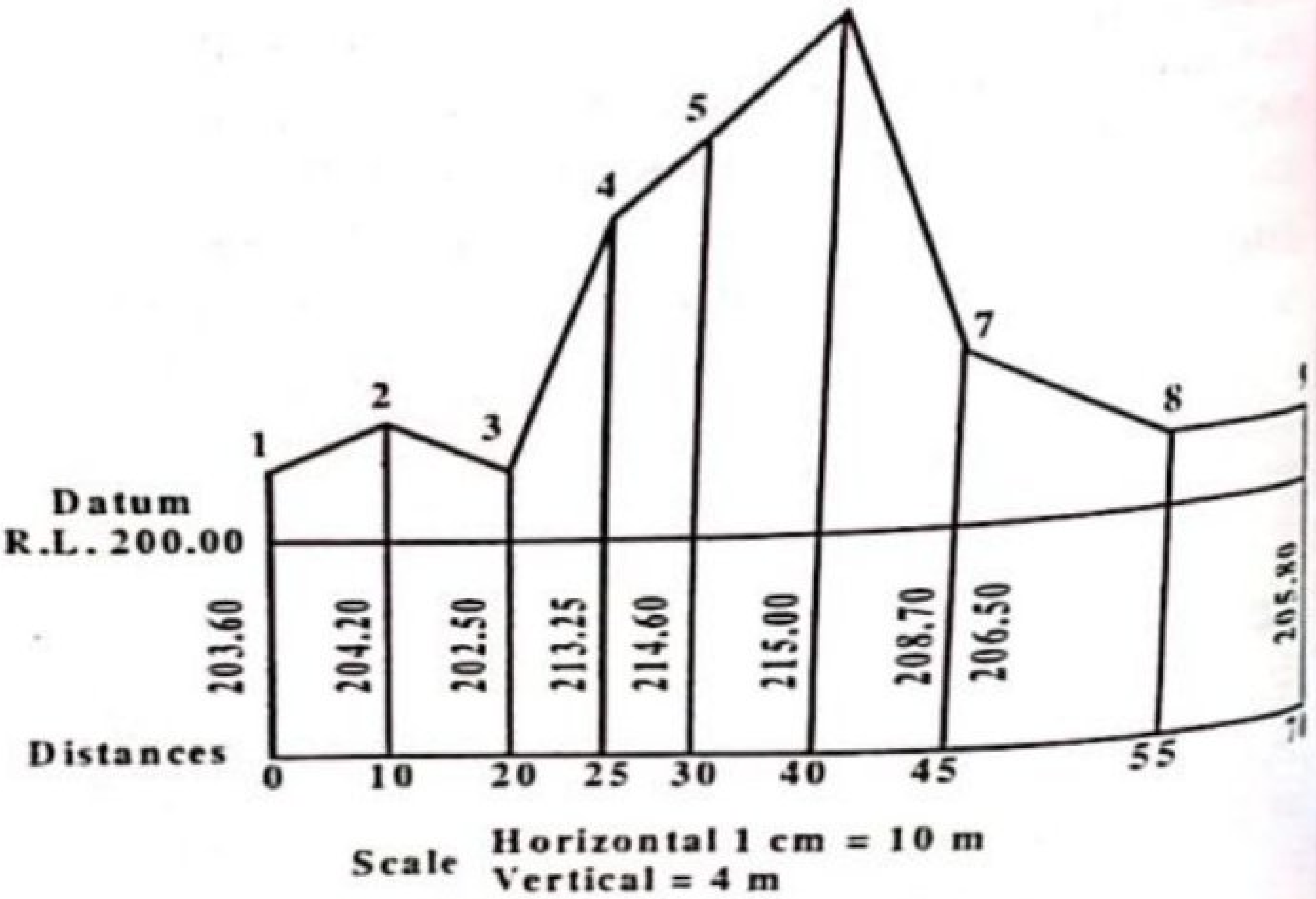


Fig. 2.63 Profile Levelling

different, the latter being about 10 times the former. The usual horizontal and vertical scales are 1 cm = 10 m and 1 cm = 1 m respectively. The vertical scale is exaggerated so that inequalities of ground are seen more apparent on drawing. The points are then joined and it gives the features of ground on paper. The reduced levels of all the points are also mentioned.

The data of profile levelling proves to be extremely useful to the designer. The gradient of the proposed structure can be decided and the line can be put up on the section. The possible depths of cutting and embankment with formation levels of all the points can also be easily worked out. Thus, the final section prepared by the designer gives all information on paper so as to start the work on the field.

(v) Cross-sectioning – When the width of the proposed project is not in the form of a strip of small width, but exceeds say 30 m to 60 m, it becomes necessary to take levels in transverse direction also. Such operation of levelling carried out in the crosswise direction is known as cross-sectioning and in most of the cases, the cross-sections are taken at right angles to the longitudinal line as it is very easy to set up perpendicular lines with the help of simple instruments like cross-staff, optical square, etc.

Cross-sections are usually run at constant distance along the centre-line, as shown in fig. 2.64. However, their spacing may be altered for accommodating the intervening features.

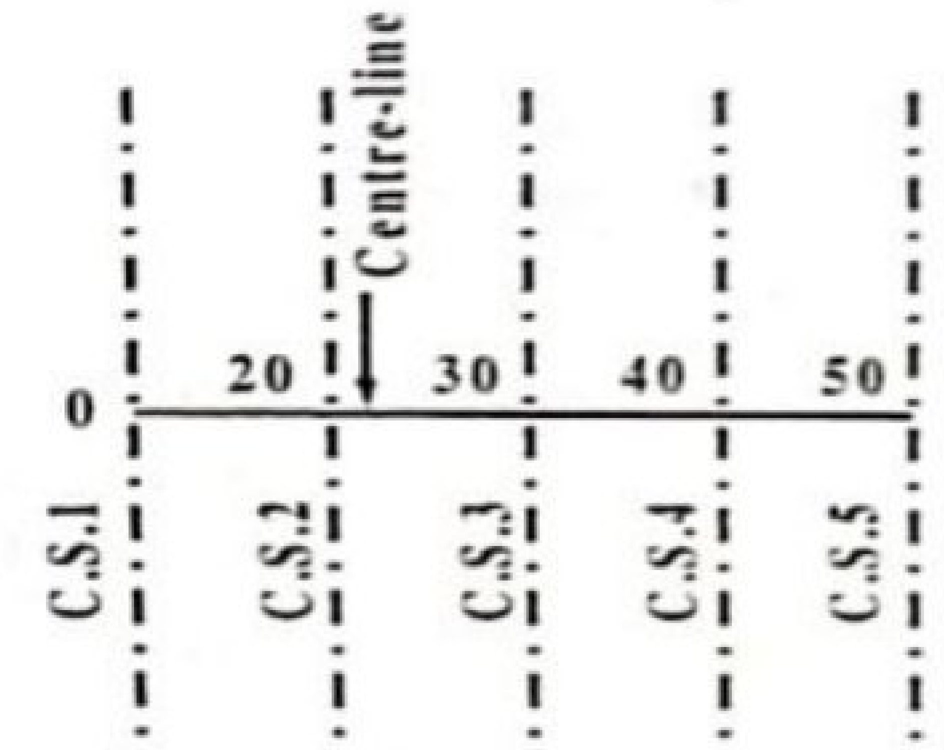
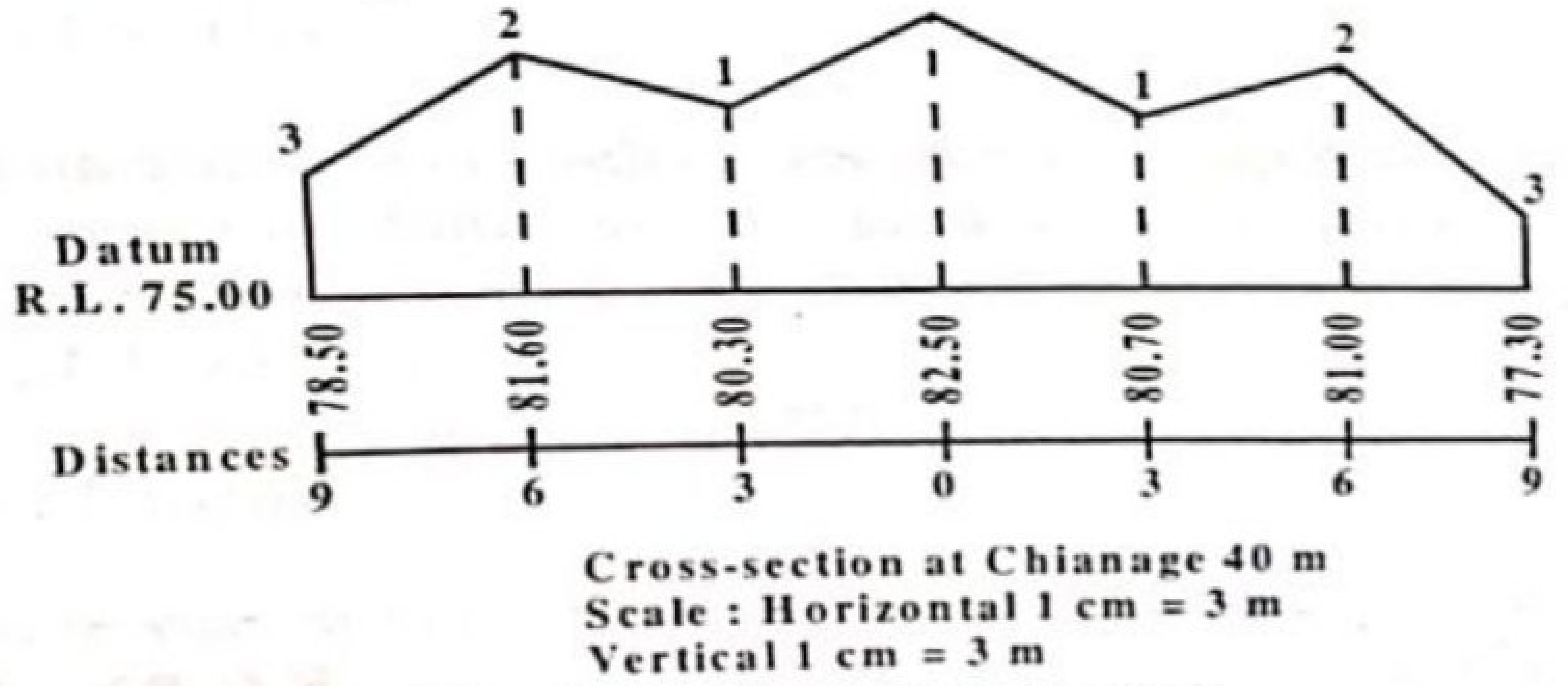


Fig. 2.64 Cross-sectioning

The length of cross-section depends on the nature of work and it may extend upto 30 m to 100 m or more. The plotting of details obtained from the cross-sectioning is carried out in the same way as that of longitudinal sectioning except that both the horizontal and vertical scales are the same. The points are then joined by straight lines to get the shape of cross-section at particular chainage, as shown in fig. 2.65.



Cross-section at Chianage 40 m
Scale : Horizontal 1 cm = 3 m
Vertical 1 cm = 3 m

Fig. 2.65 Cross-sectioning

(vi) Precise Levelling – For very accurate work, such as establishing bench marks, extra-ordinary precautions are taken in the process of levelling to eliminate all the possible errors. Such process is termed as precise levelling and the instruments used for such type of levelling are of the highest order and perfectly in working condition. While working in the field, a high degree of standard is maintained and no loop holes are kept to have any chance of error. For instance, the work of levelling is postponed on rainy and windy days. No unneccessary haste is made to complete the work. The check levels are taken in the opposite direction and preferably by another surveyor. The details obtained in the field are properly scrutinised and plotted in the office and if there is any doubt, the process is repeated.

(vii) Check Levelling – The process of levelling carried out in the reverse direction i.e. from end point to first point, just to check the difference in level between two points, worked out previously, is known as check levelling. Many shortcuts may be taken in check levelling as it is intended for checking the results of accurate levelling done before hand.

(viii) Fly Levelling – It becomes sometimes necessary to carry out levelling work along two or three alternative routes of a proposed project. Hence, if accurate levelling is adopted in such cases, it will take more time without any fruitful purpose. Hence, to get in short time the rough idea about the nature of ground, the levelling work is carried out speedily along each route. Such levelling is known as fly levelling and the accuracy desired in the fly levelling is far less than that in the check levelling.

Q.45. Explain reciprocal levelling. (R.G.P.V., June 2013, Dec. 2016)

Or

What do you mean by reciprocal levelling ? Prove that using reciprocal levelling the errors due to curvature/collimation can be eliminated.

(R.G.P.V., June 2012)

Or

What do you mean by reciprocal levelling ? Explain.

(R.G.P.V., June 2011)

Or

Prove mathematically that the errors due to curvature and refractions are removed by reciprocal levelling. Derive suitable formula for finding true difference of elevation between two points using reciprocal levelling.

(R.G.P.V., Dec. 2011)

Or

Explain reciprocal levelling in detail. (R.G.P.V., Dec. 2014)

Or

Prove that the curvature and refraction errors are eliminated in reciprocal levelling. (R.G.P.V., June 2014)

Or

Define reciprocal levelling. ***(R.G.P.V., Dec. 2015)***

Or

What is reciprocal levelling ? Also define reciprocal levelling.
(R.G.P.V., June 2016)

Ans. The process of reciprocal levelling is adopted to calculate accurately the true difference in levels of two points which are situated in such a way that it is not possible to set up the instrument at any intermediate position. When this method is adopted, the total error due to curvature, refraction and imperfect collimation adjustment disappears. Refer fig. 2.66 and fig. 2.67.

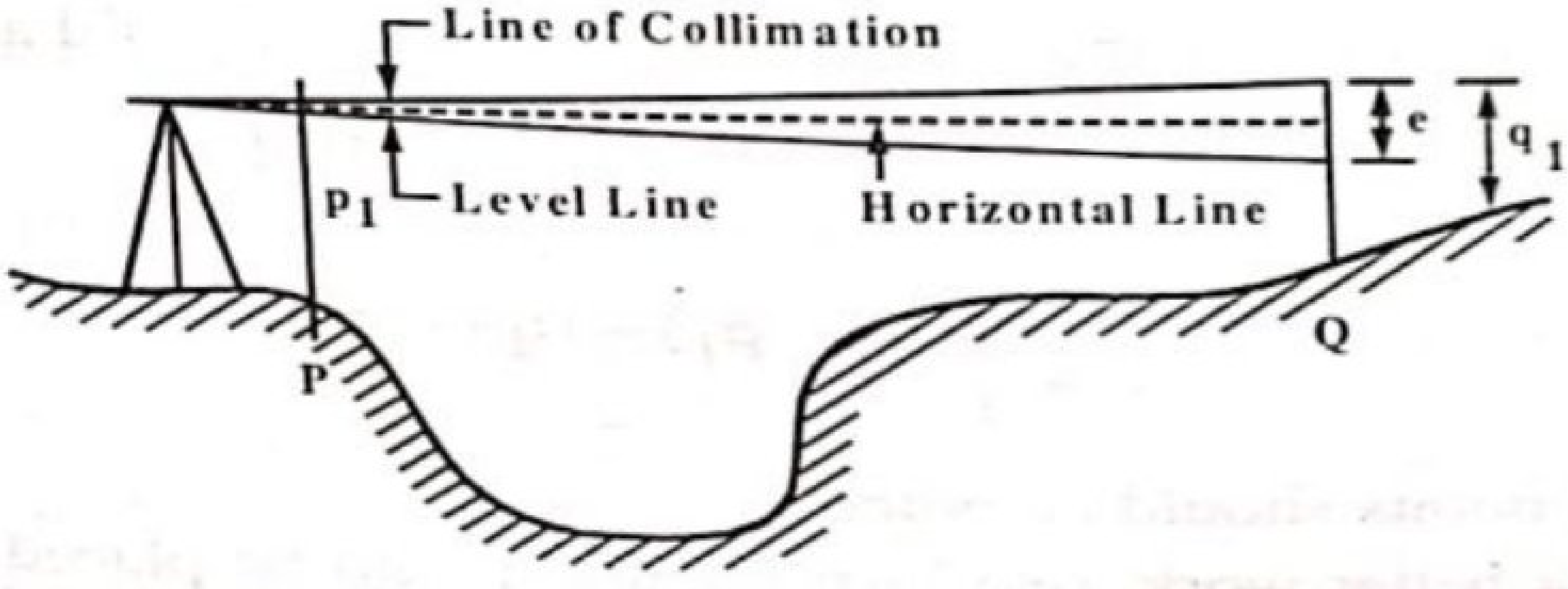


Fig. 2.66 Reciprocal Levelling

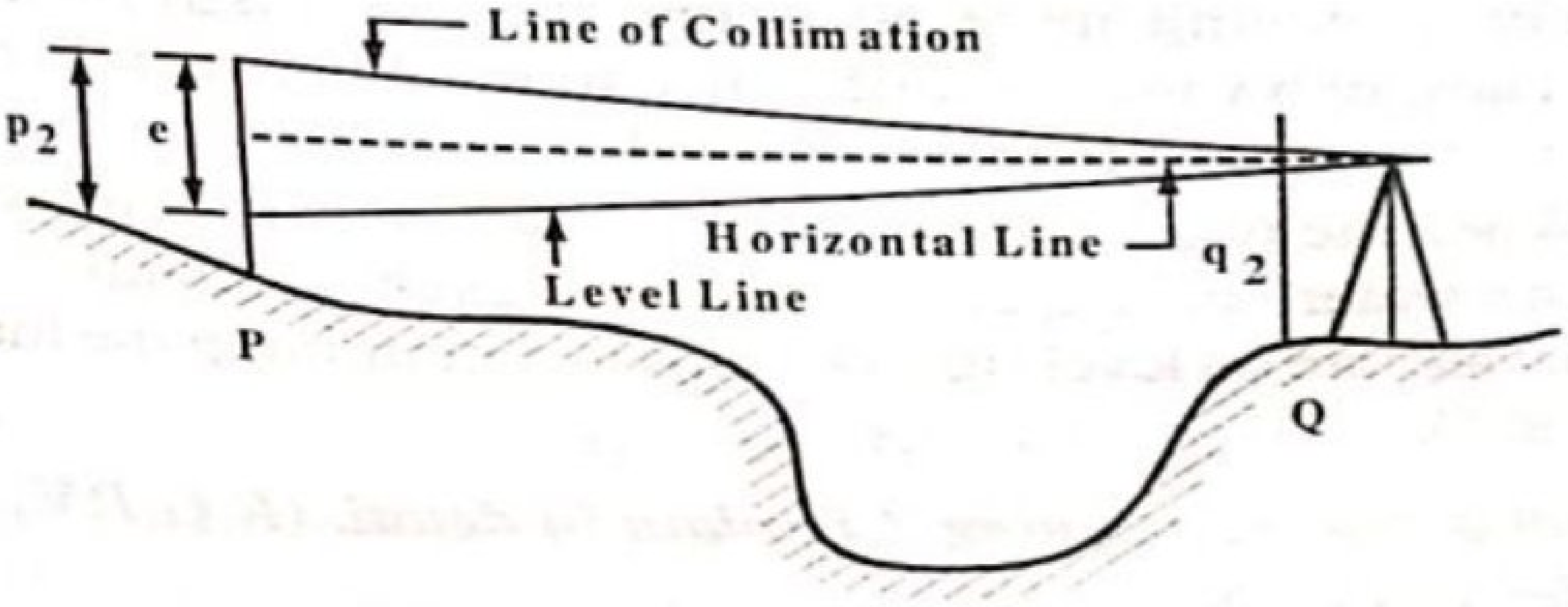


Fig. 2.67 Reciprocal Levelling

The procedure is as follows –

(i) Set up the instrument near point P and carry out the usual temporary adjustments.

(ii) Take readings on points P and Q, say p_1 and q_1. It should be noted that the reading at P should be taken through the object glass as the instrument is very near to P.

(iii) Transfer the instrument at point Q and after carrying out the usual temporary adjustments, take readings on points Q and P, say q_2 and p_2.

Let d = True difference in level of points P and Q.

e = Total error due to curvature, refraction and imperfect collimation adjustment.

Then, the true difference in level between P and Q in the first case of taking readings with the instrument at P i.e. true fall from P to Q, is given by the equation,

$$d = (q_1 - e) - p_1 = (q_1 - p_1) - e \qquad ...(i)$$

Similarly, the true difference in level between Q and P in the second case of taking readings with the instrument at Q, i.e. true fall from P to Q, is given by the equation,

$$d = q_2 - (p_2 - e) = (q_2 - p_2) + e \qquad ...(ii)$$

Solving equations (i) and (ii) for getting the values of d and e, we get

$$d = \left\{\frac{(q_1 - p_1) + (q_2 - p_2)}{2}\right\} \qquad ...(iii)$$

$$e = \left\{\frac{(q_1 - p_1) - (q_2 - p_2)}{2}\right\} \qquad ...(iv)$$

Following points should be noted –

(i) For better work, two instruments should be placed, one each at points P and Q and the readings should be taken simultaneously.

(ii) For achieving more accuracy, the two instruments should be interchanged. Thus, two values of difference in level between P and Q will be obtained. The mean value should be adopted.

(iii) When the two points are outside the range of telescope, the staff is put up on the water surface and levels are taken as usual. The fact that points lying on water are on level surface helps in determining the ture difference in level of P and Q.

Q.46. What is cross-sectioning ? Explain in detail. (R.G.P.V., June 2011)

Ans. Refer Q.44 (v).

Q.47. What do you understand by indirect levelling ? Explain in detail.

Ans. In case of methods of the indirect levelling, the relative levels of the points are found out by the indirect observations and the following are the three forms of the indirect levelling –

(i) Barometric levelling
(ii) Hypsometry
(iii) Trigonometrical levelling.

(i) ***Barometric Levelling*** – The principle that atmospheric pressure varies inversely with the altitude of a point is applied in case of barometric levelling. A barometer is therefore used in this method and the readings observed

at different points give a measure of the relative elevation of those points. The process of barometric levelling gives approximate results and it is therefore adopted in the reconnaissance or preliminary survey.

Following are the two types of barometer –

(a) Aneroid barometer (b) Mercury barometer.

(a) Aneroid Barometer – This instrument is portable and convenient to use. It is therefore commonly used in the barometric levelling. It is in the form of a thin cylindrical sealed metallic box of 8 cm to 12 cm diameter. The ends of the box are corrugated and they are sensitive to react with the outside changes of the atmosphere. The movement of the pointer on a graduated arc is magnified by suitable level arrangement. The instrument is held in the horizontal position at each point and after slight tamping, the reading is taken.

(b) Mercury Barometer – This instrument is in the form of a long glass tube about 76 cm long dipped into a cistern which is filled up with mercury. The height of mercury column is read with the help of a vernier reading upto 0.01 cm. The instrument is difficult to handle and transport and it is not commonly used in the surveying work.

The barometric readings may be taken with simple observations or with simultaneous observations. In the former case, a single barometer is moved from one point to the other for taking readings. In the latter case, two previously compared barometers are employed, one at each point, and the readings at both the points are taken simultaneously.

The difference in elevation between two points by the barometric levelling is then worked out from the following equation –

$$h = 18336.3\,(\log H_1 - \log H_2)\left(1 + \frac{T_1 + T_2}{500}\right)$$

where, h = Difference in level in m between two points
H_1 = Barometer reading in cm at the lower point
H_2 = Barometer reading in cm at the higher point
T_1 = Temperature of air in °C at the lower point
T_2 = Temperature of air in °C at the higher point.

It should be noted that T_1 and T_2 are measured by means of the detached thermometer.

(ii) Hypsometry – In hypsometry, the temperature at which water boils is taken as the basis for determining the height of a point. As the altitude increases, the atmospheric pressure decreases and due to this, the boiling point of water is lowered down. The hypsometer, also known as thermo-barometer, consists of a thermometer which is graduated to 1/10 degree C. It is held in a telescopic tube and it is suspended over a small boiler which contains rain water. A spirit lamp is provided to boil the water. The adjustment of thermometer is such that it records the temperature of the steam. The corresponding atmospheric pressure is then obtained by referring to tables and the formula of barometric levelling is then applied to find out the differences in elevation.

(iii) Trigonometrical Levelling – In case of trigonometrical levelling, the relative elevations of different stations are worked out by taking the vertical angles and measuring or computing the horizontal distances. The vertical angles are measured by means of a theodolite. The main advantage of this method is that it brings down the number of change points to a minimum even though the difference in level of two points is very great.

For example, the elevations of top of towers, mountain peaks, etc. can be determined by trigonometrical levelling.

Q.48. Describe temporary adjustments of a levelling instrument.
(R.G.P.V., June 2003, Feb. 2005, June 2005)

Ans. Every surveying instrument needs some adjustments. Generally adjustments are of two types –

(i) Temporary adjustments (ii) Permanent adjustments.

Temporary adjustments are the ones those are done at every setting of the instrument hence, these are required when setup is changed.

Permanent adjustments are made only when the fundamental relation between some parts or lines are disturbed.

The following temporary adjustments are done in case of a level –

(i) Setting up the level (ii) Levelling up (iii) Elimination of parallax.

(i) Setting Up the Level – The operation of setting up includes, fixing the instrument on the stand and levelling the instrument approximately by eye judgement. To fix the instrument on the stand, first clamp is released and instrument is fixed on the top of the tripod. Now the instrument is levelled approximately by eye judgement with the help of keep bubble in the centre, while bubble tube is provided on the tribarch.

(ii) Levelling Up – The levelling is done for the purpose of making the vertical axis of the instrument truly vertical. The levelling is done by moving the screws on the levelling head. For three screw levelling head, firstly the telescope is placed parallel to the two screws, and keep the bubble in the centre by turning these, screws inwards or outwards. The telescope is then turned through 90° so that it lies over the third screws. By turning third screw the bubble is centred. The procedure is carried out until the bubble remains in centre for both the positions, which are at right angles to each other.

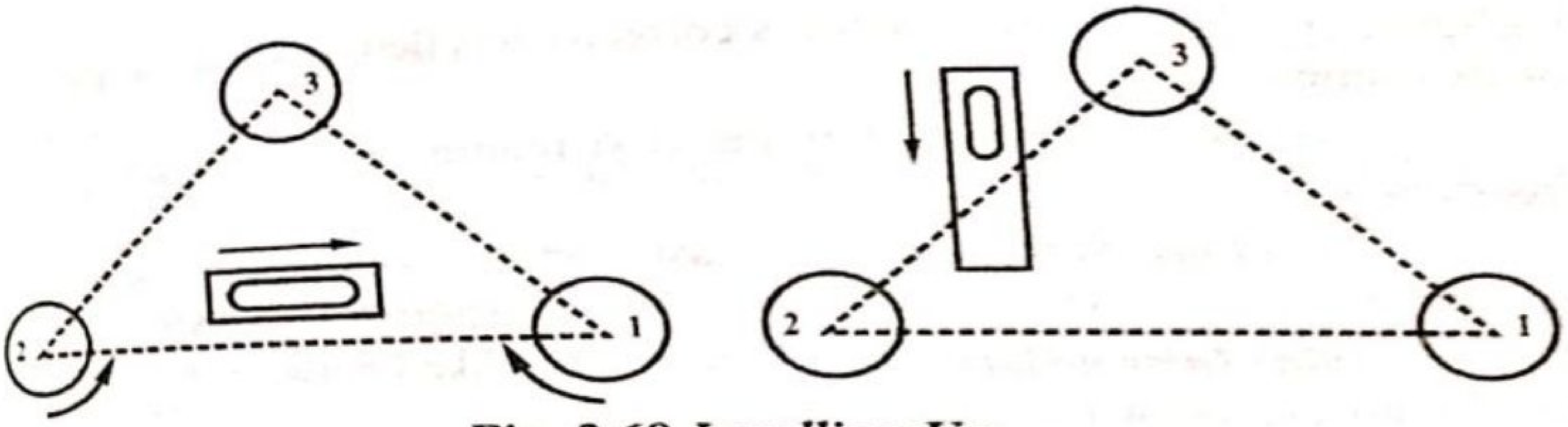


Fig. 2.68 Levelling Up

(iii) Elimination of Parallax – Parallax condition is arised when the image formed by the objective is not in the plane of the cross hairs. It is necessary to eliminate this type of condition so that it can be eliminated in two steps –

(a) By focussing the eye-piece (b) By focussing the objective.

(a) Focussing the Eye-piece – To focus the eye-piece, keep a white paper in front of the objective and move eye-piece in or out till the cross-hairs are seen sharp and distinct.

(b) Focussing the Objective – Now the telescope is directed towards the staff and focussing screw is turned till the image appears clear and sharp.

Q.49. Define following terms –

(i) Bench mark (R.G.P.V., June 2005, Dec. 2006)
(ii) Change point (R.G.P.V., Dec. 2003, 2006, June 2009, 2010)
(iii) Reduced level
(iv) Line of collimation (R.G.P.V., June 2003, Dec. 2003)
(v) Height of instrument (R.G.P.V., Dec. 2003, 2006, June 2009)
(vi) Back sight (R.G.P.V., June 2009)
(vii) Fore sight (R.G.P.V., June 2003, Dec. 2003)
(viii) Intermediate sight.

Ans.(i) Bench Mark – A fixed point of known elevation is called the bench mark.

(ii) Change Point – The point indicating the shifting of level is known as a change point or turning point.

(iii) Reduced Level – The reduced level of a point is its height relative to the datum.

(iv) Line of Collimation – The line joining the intersection of cross-hair and optical centre of the object glass and its continuation is known as line of collimation. It is also called as line of sight.

(v) Height of Instrument – The elevation or R.L. of the line of collimation, when the instrument is correctly levelled, is known as the height of instrument.

(vi) Back Sight – It is the first reading from any set up of the instrument.

(vii) Fore Sight – It is the last reading taken before disturbing the instrument from its set up. It is also called as ***negative fore sight***.

(viii) Intermediate Sight – All sights taken between back sight and fore sights are known as intermediate sights.

Q.50. What is bench mark ? Write their types in order of importance and accuracy. ***(R.G.P.V., Dec. 2003)***

Ans. **Bench Mark** – Refer Q.49 (i).

Depending upon the permanency and the precision, bench marks may be done into four main types i.e.

(i) G.T.S. bench marks (ii) Permanent bench marks
(iii) Arbitrary bench marks (iv) Temporary bench marks.

(i) G.T.S. Bench Marks – These bench marks are established by the Survey of India with greatest precision at an interval of about 100 kms all over the country. Their elevations refer to the mean sea level datum of Bombay port obtained by hourly observations of the tides over a period of 19 years. G.T.S. bench marks falling in belts of area bounded by 1° latitude and 1° longitude are published in levelling pamphlet.

(ii) Permanent Bench Marks – These bench marks are established between G.T.S. bench marks by the Survey of India or other government agencies such as P.W.D., on clearly defined and permanent natural or cultural detail points such as isolated rocks culverts, kilometre stones, railway platforms, gate pillars of inspection houses etc. The permanent bench marks established by the survey of India contain the inscripts G.T.S. and their elevations are also available in the levelling pamphlet of B.M. the area. P.W.D. bench marks are marked on a plane surface by a rectangle such as below or above the rectangle, letters B.M. along with R.L. of the bench mark are also cut and filled in Japan black.

(iii) Arbitrary Bench Marks – These are the reference points whose elevations are arbitrary assumed for, small levelling operations. Their elevations do not refer to any fixed datum as in the case of G.T.S. or permanent bench marks.

(iv) Temporary Bench Marks – These are the reference points on which a day's work is closed and when continued next day. Their elevations are referred to as the reduced levels. Such bench marks should be carefully established on permanent points such as km stone, parapet, floor of verandah, roots of trees etc and their correct descriptions should also be written in the level book.

Q.51. Stating various types of bench marks, define G.T.S. bench mark.
(R.G.P.V., Dec. 2014)

Ans. Refer Q.50.

Q.52. How will you find out reduced levels of points from the observed staff readings.

Or

Describe rise and fall method of computing levels with suitable example.
(R.G.P.V., June/July 2006, Nov./Dec. 2007, Dec. 2008)

Ans. There are two methods of finding the reduced levels of points from the observed staff readings –

(i) Collimation or height of instrument method
(ii) Rise and fall method.

(i) Collimation or Height of Instrument Method – In this method, the height of the instrument is calculated for each setting of the instrument by adding the back sight to the elevation of the B.M. Then the R.L. of the intermediate point is obtained by subtracting the intermediate sight from the height of the instrument. Then the R.L. of the turning point is obtained by subtracting the fore sight from the height of the instrument.

For the next setting of the instrument, the H.I. is obtained by adding the B.S. taken on turning point to its R.L. The process is continue till the R.L. of the last point is obtained by subtracting the F.S. from H.I. of the last setting.

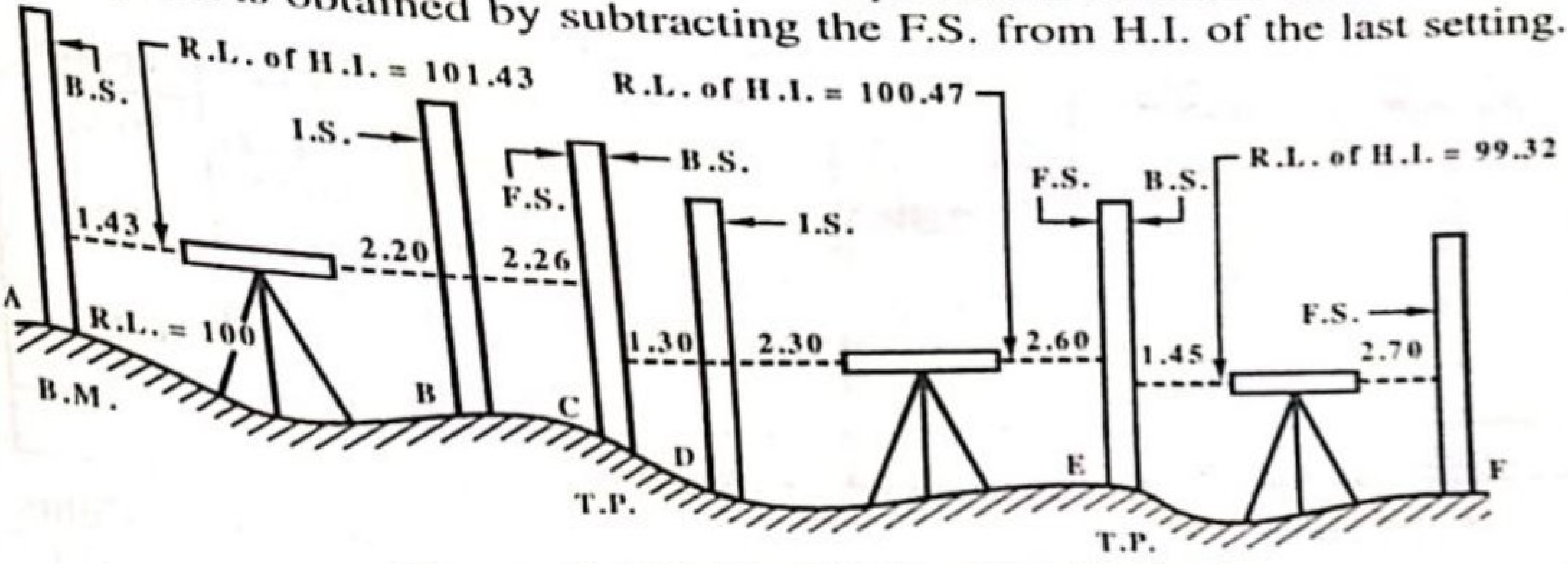


Fig. 2.69 Height of Instrument Method

Table 2.7 shows a page of the level book for the H.I. method. For the illustration of differential given in fig. 2.70, the back sight of the stations is 1.430. As the R.L. of the point A, which is a bench mark is 100, so that the H.I. is 101.430.

R.L. of A = 100.00, assumed

(i) R.L. of H.I. in
Ist setting = R.L. of A + Staff reading at station 'A' (B.S.)
= 100 + 1.43 = 101.43
R.L. of B = H.I. – Staff reading at 'B' (I.S.)
= 101.43 – 2.20 = 99.23
R.L. of C = H.I. – Staff reading at 'C'(F.S.)
= 101.43 – 2.26 = 99.17

(ii) R.L. of H.I. in
IInd setting = R.L. of C + Staff reading at 'A' (B.S.)
= 99.17 + 1.30 = 100.47
R.L. of D = H.I. – Staff reading at 'D' (I.S.)
= 100.47– 2. 30 = 98.17
R.L. of E = H.I. – Staff reading at 'E' (F.S.)
= 100.47 – 2.60 = 97.87

(iii) R.L. of H.I. in
IIIrd setting = R.L. of E + Staff reading 'E' (B.S.)
= 97.87 + 1.45 = 99.32
R.L. of F = H.I. – Staff reading 'F' (F.S.)
= 99.32 – 2.70 = 96.62

Generalised Formulae

$$\boxed{\text{R.L.} = \text{H.I.} - \text{I.S. or F.S.}}$$

$$\boxed{\text{H.I.} = \text{R.L.} + \text{B.S.}}$$

Table 2.7

Station	*B.S.*	*I.S.*	*F.S.*	*H.I.*	*R.L.*	*Remark*
A	1.43			101.43	100.00	B.M.
B		2.20			99.23	
C	1.30		2.26	100.47	99.17	C.P.
D		2.30			98.17	
E	1.45		2.60	99.32	97.87	C.P.
F			2.70		96.62	
Sum	4.18	4.50	7.56			

Arithmetic Check – The difference between the sum of back sights and that of fore sights must be equal to the difference between the last R.L. and first R.L. thus,

Σ B.S. – Σ F.S. = Last R.L – First R.L.
4.18 – 7.56 = 96.62 – 100.00
3.38 = 3.38

(Hence O.K.)

Note – Stations, those are having B.S. reading there will be separate H.I. for each B.S. reading.

(ii) Rise and Fall Method – In this method, the difference of level between consecutive points is found by comparing the staff readings on the two points for the same setting of the instrument. If the forward staff reading is smaller, it indicate the rise and if greater, it indicate the fall. By adding rise or subtracting the fall, R.L. of each point can be obtained.

Table 2.8 shows a page of level book for the rise and fall method. By considering fig. 2.70, the R.L. of the point 'A' which is a bench mark is 100.

First findout the rise and fall at two consecutive different stations.

Point B (with respect to B.M.)

= Staff reading at station 'A' – Staff reading at station 'B'

= 0.80 – 1.20

= – 0.40 (Fall)

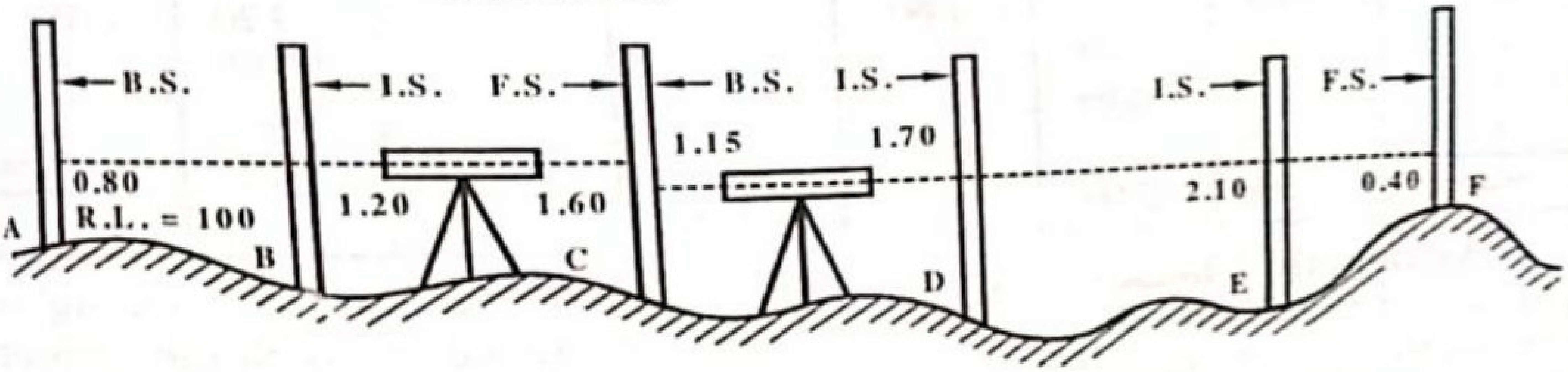


Fig. 2.70 Rise and Fall Method

Point C (with respect to B)

= Staff reading at station 'B' – Staff reading at station 'C'

= 1.20 – 1.60 = – 0.40 (Fall)

Point D (with respect to C)

= Staff reading at station 'C' – Staff reading at station 'D'

= 1.15 – 1.70 = – 0.55 (Fall)

Point E (with respect to D)

= Staff reading at station 'D' – Staff reading at station 'E'

= 1.70 – 2.10 = – 0.40 (Fall)

Point F (with respect to E)

= Staff reading at station 'E' – Staff reading at station 'F'

= 2.10 – 0.40 = + 1.70 (Rise)

R.L. of B. M.= 100.00

R.L. of B = R.L. of 'A' – Fall at station 'B'

= 100.00 – 0.40 = 99.60

R.L. of C = R.L. of station 'B' – Fall at station 'C'

= 99.60 – 0.40 = 99.20

R.L. of D = R.L. of station 'C' – Fall at station 'D'
= 99.20 – 0.55 = 98.65

R.L. of E = R.L. of station 'D' – Fall at station 'E'
= 98.65 – 0.40 = 98.25

R.L. of F = R.L. of station 'E' + Rise at station 'F'
= 98.25 + 1.70 = 99.95

Generalised Formulae

R.L. of Next Station = R.L. of preceding station – Fall

OR

= R.L. of Preceding station + Rise

Table 2.8

Station	*B.S.*	*I.S.*	*F.S.*	*Rise*	*Fall*	*R.L.*	*Remark*
A	0.80					100.00	B.M
B		1.20			0.40	99.60	
C	1.15		1.60		0.40	99.20	C.P.
D		1.70			0.55	98.65	
E		2.10			0.40	98.25	
F			0.40	1.70		99.95	
Sum	1.95	5.00	2.00	1.70	1.75		

Arithmetic Check – The difference between the sum of back sights and sum of fore sights should be equal to the difference between the sum of rise and the sum of fall and should also be equal to the difference between the R.L. of last and first point. Thus,

$$\Sigma B.S. - \Sigma F.S. = \Sigma \text{Rise} - \Sigma \text{Fall}$$
$$= \text{Last R.L.} - \text{First R.L.}$$
$$1.95 - 2.00 = 1.70 - 1.75 = 99.95 - 100.00$$
$$\mathbf{-0.05 = -0.05 = -0.05}$$

(Hence O.K.)

Q.53. Compare height of instrument and rise and fall method.

Ans. Comparison between height of instrument and rise and fall method are given below –

S.No.	*Height of Instrument Method*	*Rise and Fall Method*
(i)	It is more rapid as it involves few calculations.	It is laborious,as it involves several calculations.
(ii)	It is less tedious and simple.	It is more tedious and typical.
(iii)	There is no check on the R.L. of intermediate points.	There is a check on the R.L. of intermediate points.
(iv)	Errors in intermediate R.L. can be detected.	Errors in intermediate R.L. can be detected.

(v)	There are two check on the R.L. calculations.	There are three check on the R.L. calculations.
(vi)	It is suitable, where it is required to take number of readings from the same instrument setting such as for profile levelling.	It is suitable for fly levelling where there are no intermediate sights.

Q.54. How will you find out the R.L. when B.M. or staff station is above the line of sight ?

Ans. It becomes sometimes necessary to adopt the underside of a girder, a string course, beam, lintel or some such feature to adopt as a B.M. and the situation arises in which the point is above the line of sight. A very simple operation is performed to overcome this difficulty. The staff is held inverted on the point and the reading is taken and it is designated as negative. It is treated either as negative F.S. or negative B.S., as the case may be. A note stating that the reading is taken by keeping the staff in inverted position is entered in the remarks column.

As far as possible, the situation leading to the inverted staff reading should be avoided.

Following are the disadvantages of holding the staff inverted –

(i) In some cases, it may prove very difficult to keep the zero of the staff in line with the point whose level is required.

(ii) It is difficult to keep the staff truly vertical.

(iii) The proper sign may not be given while booking the reading.

(iv) The staff may read wrong.

NUMERICAL PROBLEMS

Prob.17. The following staff readings were observed successively with a level, the instrument is moved after fourth and sixth readings –

2.25, 1.50, 0.95, 2.10, 2.90, 1.54, 0.75, 1.95, 2.10 m.

Enter the above readings in a page of a level book and calculate the R.L. of points by height of instrument method, if the first reading was taken with a staff held on a bench mark of 500 m.

Sol. The reduced levels of the points may be calculated by height of instrument method as tabulated below –

Station	*B.S.*	*I.S.*	*F.S.*	*H.I.*	*R.L.*	*Remark*
A	2.25			502.25	500.00	B.M.
B		1.50			500.75	
C		0.95			501.30	

D	2.90		2.10	503.05	500.15	C.P.-1
E	0.75		1.54	502.26	501.51	C.P.-2
F		1.95			500.31	
G			2.10		500.16	
Sum	5.90	4.40	5.74			

Since the instrument was shifted after fourth and sixth readings, these readings will be entered. in the F.S. Column and therefore, fifth and seventh reading will be entered in B.S. column. Also the first reading will be entered in the B.S. column and the last reading in the F.S. column. All other readings will be entered in the I.S. column.

R.L. of station 'A' is given **500 m**

H.I. at station 'A' = R.L. of station 'A' + B.S. at station 'A'

= 500 + 2.25 = 502.25 m

R.L. of station 'B' = H.I. – I.S. at station 'B'

= 502.25 – 1.50 = **500.75 m**

R.L. of station 'C' = H.I. – I.S. at station 'C'

= 502.25 – 0.95 = **501.30 m**

R.L. of station 'D' = H.I. – F.S. at station 'D'

= 502.25 – 2.10 = **500.15 m**

H.I. at station 'D'= R.L. of station 'D' + B.S. at station 'D'

= 500.15 + 2.90

= 503.05 m

Every station having reading at B.S. will have separate H.I.

R.L. at station 'E' = H.I. – I.S. at station 'E' = 503.05 – 1.54 = **501.51 m**

H.I. at station 'E' = R.L. of station 'E' + B.S. at station 'E'

= 501.51 + 0.75

= 502.26 m

R.L. of station 'F' = H.I. – I.S. at station 'F' = 502.26 – 1.95 = **500.31 m**

R.L. of station 'G' = H.I. – F.S. at station 'G' = 502.26 – 2.10 = **500.16 m**

Arithmetic Check –

$$\Sigma \text{ B.S.} - \Sigma \text{ F.S.} = \text{Last R.L.} - \text{First R.L.}$$

$$5.90 - 5.74 = 500.16 - 500.00$$

$$\mathbf{0.16 = 0.16}$$ **(Hence O.K.)**

Prob.18. The following readings were observed successively with a level, the instrument having been moved after third, sixth and eighth readings – 2.220, 1.616, 0.978, 2.090, 2.764, 1.622, 0.602, 1.983, 1.045, 2.654 metres.

Enter the above reading in a page of a level book and calculate the R.L. of points if the first reading was taken with a staff held on a bench mark of 400 m. ***(R.G.P.V., Dec. 2015)***

Sol.

Station	B.S.	I.S.	F.S.	H.I.	R.L.	Remark
A	2.220			402.22	400	
B		1.616			400.604	
C	2.090		0.978	403.332	401.242	C.P.-1
D		2.764			400.568	
E	0.602		1.622	402.312	401.710	C.P.-2
F	1.045		1.983	401.374	400.329	C.P.-3
G			2.654		398.72	
	5.957		7.237			

Arithmetic Check –

$$\Sigma \text{B.S.} - \Sigma \text{F.S.} = \text{Last R.L.} - \text{First R.L.}$$
$$5.957 - 7.237 = 398.72 - 400$$
$$\mathbf{-1.28 = -1.28}$$

(Hence O.K.)

***Prob.19.** The following consecutive reading were taken by a level 0.975, 1.225, 1.465, 1.025, 1.825, 1.355, 0.785, 0.235, 2.135, 1.225, 3.160. The instrument was shifted after fourth and seventh readings. Enter the data in level book and calculate R.L. of all points by any one method if the first reading was taken on B.M. 100.0 m.* *(R.G.P.V., June 2015)*

Sol. Similar as Prob.18.

***Prob.20.** The following staff readings were taken with a level which was shifted after 4th, 7th and 10th reading – 2.235, 1.616, 0.960, 2.090, 2.840, 1.622, 1.930, 1.983, 1.045, 2.150, 2.370, 2.654 metres. Assuming the R.L. of starting point as 350.00 m, enter the readings in the form of level book page and calculate the R.L. of points.* *(R.G.P.V., June 2016)*

Sol.

Station	B.S.	I.S.	F.S.	H.I.	R.L.	Remark
A	2.235			352.235	350	B.M.
B		1.616			350.619	
C		0.960			351.275	
D	2.840		2.090	352.985	350.145	C.P.-1
E		1.622			351.363	
F	1.983		1.930	353.038	351.055	C.P.-2
G		1.045			351.993	
H	2.370		2.150	353.258	350.888	C.P.-3
I			2.654		350.604	
	9.428		8.824			

Arithmetic Check –

$$\Sigma \text{ B.S.} - \Sigma \text{ F.S.} = \text{Last R.L.} - \text{First R.L.}$$

$$9.428 - 8.824 = 350.604 - 350$$

$$\mathbf{0.604 = 0.604} \qquad \textbf{(Hence O.K.)}$$

Prob.21. The following consecutive readings were taken with the help of dumpy level.

1.905, 2.655, 3.905, 4.025, 1.965, 1.705, 1.595, 1.265, 2.545, 2.005, 3.145.

The instrument was shifted after the fourth and seventh readings. The first reading was taken on the staff held on B.M. of R.L. 100.000 m. Rule out a page of level field book, enter the above readings there on. Calculate the R.Ls. of the points and apply the arithmetic check. (R.G.P.V., Dec. 2012)

Sol. Similar as Prob.20.

Prob.22. Following staff readings (in metre) were observed successively with level, the instrument having been shifted after the 2nd, 4th and 8th readings.

0.875, 1.235, 2.310, 1.385, 2.930, 3.125, 4.125, 0.120, 1.875, 2.030, 3.765.

The first reading was taken with the staff held upon a benchmark of elevation 142.870 m. Enter the readings in level book page and reduce levels. Apply usual checks also. (R.G.P.V., June 2012)

Sol. Similar as Prob.20.

Prob.23. The following consecutive readings were taken with a level and a 4.0 m staff on a continuously sloping ground at a common interval of 30 m.

0.780, 1.535, 1.955, 2.430, 2.985, 3.480, 1.155, 1.960, 2.365, 3.640, 0.935, 1.045, 1.630 and 2.545.

The reduced level of the first point 'A' was 180.750 m rule out a page of a level field book and enter the above readings. Calculate the reduced levels of the points by the collimation system. Also calculate the gradient of the line joining the first and the last point. (R.G.P.V., Dec. 2014)

Sol.

Station	*B.S.*	*I.S.*	*F.S.*	*H.I.*	*R.L.*	*Remark*
A	0.780			181.53	180.750	BM
B		1.535			179.995	
C		1.955			179.575	
D		2.430			179.10	
E		2.985			178.545	
F	1.155		3.480	179.205	178.05	CP_1
G		1.960			177.245	
H		2.365			176.84	

	0.935		3.640	176.5	175.565	CP_2
I		1.045			175.455	
J		1.630			174.87	
K			2.545		173.955	
L			9.665			
	2.87					

Arithmetic check –

$$\Sigma BS - \Sigma FS = \text{Last RL} - \text{First RL}$$

$$2.87 - 9.665 = 173.955 - 180.750$$

$$-6.795 = -6.795$$

(Hence O.K.)

$$\text{Gradient of the line} = \frac{\text{Difference in level}}{\text{Horizontal distance}} = \frac{6.795}{30 \times 11} = 1 \text{ in } 48.56$$ **Ans.**

Prob.24. The following consecutive readings were taken with a level and a 4.0 m staff on a continuously sloping ground at common interval of 30 m. 0.780, 1.535, 1.955, 2.430, 2.985, 3.480, 1.155, 1.960, 2.365, 3.640, 0.935, 1.045, 1.630 and 2.545. The reduced level of the first point 'A' was 180.750 m. Rule out a page of a level field book and enter the above readings. Calculate the reduced levels of all the points and apply proper check for calculation. ***(R.G.P.V., June 2013)***

Sol. Similar as Prob.23.

Prob.25. Following consecutive readings were taken on a continuously sloping ground at regular interval of 30 m. Find the gradient joining first and last point (using 3 m levelling staff) 1.370 m, 2.055 m, 2.760 m, 0.455 m, 1.110 m, 1.875 m, 2.57 m, 0.305 m, 0.995 m, 1.685 m. Enter the above readings in a page of field and level book. Deduce RL of intermediate points using H.I. method. ***(R.G.P.V., June 2014)***

Sol. Similar as Prob.23.

Prob.26. The following consecutive readings were taken with a dumpy level along a chain line at a common interval of 15 m. The R.L. of B.M. is 150. The instrument was shifted after the fourth and ninth readings.

3.450, 2.54, 1.25, 0.75, 3.25, 2.50, 1.85, 1.45, 1.95, 1.50, 2.50 and 3.05 m. Find the R.L. of all points by rise and fall method.

Sol. The R.Ls of the points may be calculated by rise and fall method as tabulated below –

Stations	*B.S.*	*I.S.*	*F.S.*	*Rise*	*Fall*	*R.L.*	*Remark*
A	3.450					150	B.M.
B		2.54		0.91		150.91	
C		1.25		1.29		152.20	
D	3.25		0.75	0.50		152.70	C.P.- 1

E		2.50		0.75		153.45	
F		1.85		0.65		154.10	
G		1.45		0.40		154.50	
H	1.50		1.95		0.50	154.00	C.P.- 2
I		2.50			1.00	153.00	
J			3.05		0.55	152.45	
Sum	8.20	12.09	5.75	4.50	2.05		

Since the instrument was shifted after fourth and ninth readings, these readings will be entered in the F.S. column and therefore fifth and tenth readings will be entered in B.S. column. Also the first reading will be entered in the B.S. column and the last reading in the F.S. column. All other readings will be entered in the I.S. column.

R.L. of station 'A' = **150 m** (Given)

∵ Rise of station 'B' = Staff reading at station 'A' – Staff reading at station 'B'
= 3.450 – 2.54 = 0.91 m (Rise)

∴ R.L. of station 'B' = R.L. of station 'A' + Rise of station 'B'
= 150 + 0.91 = **150.91 m** **Ans.**

∵ Rise of station 'C' = Staff reading at station 'B' – Staff reading at station 'C'
= 2.54 –1.25 = 1.29 m (Rise)

∴ R.L. of station 'C' = R.L. of station 'B' + Rise of station 'C'
= 150.91 + 1.29 = **152.20 m** **Ans.**

∵ Rise of station 'D' = Staff reading at station 'C' – Staff reading at D
= 1.25 – 0.75 = 0.50 m (Rise)

∴ R.L. of station 'D' = R.L. of station 'C' – Rise of station 'D'
= 152.20 + 0.50 = **152.70 m** **Ans.**

As station 'D' is the change point so as for finding out R.L. of station 'E' the B.S. will be taken as staff reading at station 'D'

∵ Rise of station 'E' = Staff reading at station 'D' – Staff reading at 'E'
= 3.25 – 2.50 = 0.75 m (Rise)

∴ R.L. of station 'E' = R.L. of station 'D' + Rise of station 'E'
= 152.70 + 0.75 = **153.45 m** **Ans.**

∵ Rise of station 'F' = Staff reading at 'E' – Staff reading at 'F'
= 2.50 – 1.85 = 0.65 m (Rise)

∴ R.L. of station 'F' = R.L. of station 'E' + Rise of station 'F'
= 153.45 + 0.65 = **154.10 m** **Ans.**

∵ Rise of station 'G' = Staff reading at 'F' – Staff reading at 'G'
= 1.85 – 1.45 = 0.40 m (rise)

∴ R.L. of station 'G' = R.L. of station 'F' + Rise of station 'G'
= 154.10 + 0.40 = **154.50 m** **Ans.**

∵ Fall at station 'H' = Staff reading at station 'G' – Staff reading at station 'H'
= 1.45 – 1.95 = 0.50 (–ve) (Fall)

∴ R.L. of station 'H' = R.L. of station 'G' – Fall at station 'H'
= 154.50 – 0.50 = **154.00 m** **Ans.**

∵ Fall at station 'I' = Staff reading at station 'H' – Staff reading at station 'I'
= 1.50 – 2.50 = 1.00 (–ve) (Fall)

∴ R.L. of station 'I' = R.L. of station 'H' – Fall of station 'I'
= 154.00 – 1.00 = **153.00 m** **Ans.**

∵ Fall at station 'J' = Staff reading at station 'I' – Staff reading at 'J'
= 2.50 – 3.05 = 0.55 (–ve) (Fall)

∴ R.L. of station 'J' = R.L. of station 'I' – Fall at station 'J'
= 153.00 – 0.55 = **152.45 m** **Ans.**

Arithmetic Check –

$$\Sigma B.S. - \Sigma F.S. = \Sigma Rise - \Sigma Fall = \text{Last R.L.} - \text{First R.L.}$$
$$8.20 - 5.75 = 4.50 - 2.05 = 152.45 - 150$$
$$\mathbf{2.45 = 2.45 = 2.45}$$ **(Hence O.K.)**

Prob.27. The following consecutive staff readings were taken with a level and 3 m levelling staff on a continuously slopping ground at a common interval of 20 m : 0.605, 1.235, 1.860, 2.575, 0.240, 0.915, 1.935, 2.875, 1.825, 2.725. The RL of the first point was 192.120. Rule a page of a level field book and enter the above readings. Calculate the reduced levels of the points and also the gradient of the line joining the first and last points.
(R.G.P.V., Dec. 2013)

Sol.

Station	*B.S.*	*I.S.*	*F.S.*	*Rise*	*Fall*	*R.L.*	*Remark*
A	0.605					192.120	
B		1.235			0.63	191.49	
C		1.860			0.625	190.865	
D	0.240		2.575		0.715	190.15	
E		0.915			0.675	189.475	
F		1.935			1.02	188.455	
G	1.825		2.875		0.94	187.515	
H			2.725		0.90	186.615	
	2.67		8.175		5.505		

Arithmetic check –

$$\Sigma B.S. - \Sigma F.S. = \Sigma Rise - \Sigma Fall = \text{Last R.L.} - \text{First R.L.}$$
$$2.67 - 8.175 = 00 - 5.505 = 186.615 - 192.120$$
$$-5.505 = -5.505 = -5.505$$

Gradient of line joining first and last point, i.e. line AI

$$= \frac{\text{Difference in level}}{\text{Horizontal distance}} = \frac{5.505}{160} = \frac{1}{29.06} \text{ i.e. 1 in 29.06}$$ **Ans.**

Prob.28. The following successive readings were taken with a dumpy level along a chain line at common intervals of 20 m. The R.L. of first station was 120.50 m. The dumpy level was shifted after third, sixth and eighth reading. Calculate R.L. of each station and also find gradient of the line joining first and last station. The readings are –

0.945 m, 1.270 m, 1.890 m, 0.655 m, 1.355 m, 1.980 m, 0.730 m, 1.675 m, 0.985 m, 1.805 m, 2.150 m, 3.010 m.

(R.G.P.V., Dec. 2011)

Sol. Similar as Prob.27.

THEODOLITES

Q.55. What do you mean by the term theodolite ?

Or

What are the main function of a theodolite ? (R.G.P.V., June 2015)

Ans. It is an instrument which is used mainly for accurate measurement of horizontal and vertical angles up to 10' or 20'. Theodolite is used for following purposes –

(i) To find out the vertical height of an object
(ii) To measure the horizontal distance between two points.
(iii) Measurement of horizontal angles.
(iv) Measurement of vertical angles.
(v) Measurement of magnetic bearings of lines.
(vi) Measurement of direct angles.
(vii) Measurement of deflection angles.
(viii) Prolongation of straight lines.
(ix) Running a straight line between two points.
(x) Laying off an angle by repetition method.

Q.56. Explain different types of theodolite. (R.G.P.V., Dec. 2016)

Or

What do you mean by transit and non-transit theodolite ?

(R.G.P.V., June 2014)

Ans. Theodolite is of two types –

(i) Transit theodolite
(ii) Non-transit theodolite.

(i) Transit Theodolite – In this type of theodolite, the telescope can be revolved through 180° in a vertical plane about its horizontal axis.

(ii) Non-transit Theodolite – In this type of theodolite, the telescope can not be revolved through 180° in a vertical plane about its horizontal axis.

A line diagram of a transit theodolite is shown in fig. 2.71. It consists of alidade assembly at the top, the horizontal circle assembly in the middle and the levelling head assembly at the bottom.

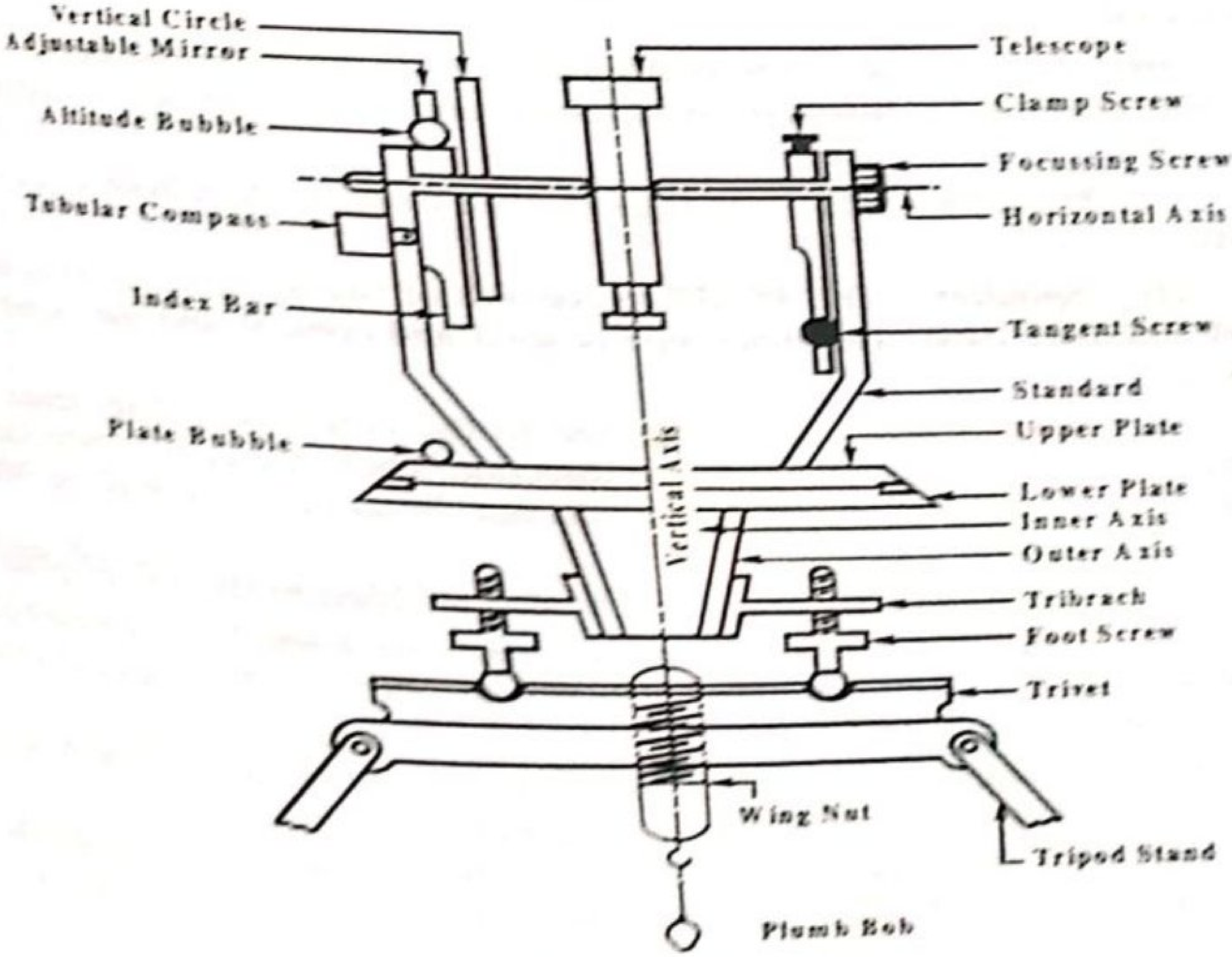


Fig. 2.71 Theodolite

(i) Alidade Assembly – It is the topmost assembly, which includes a telescope supported by two standards of the shape of letter A. An altitude bubble is attached to the standards.

(ii) Horizontal Circle Assembly – It consists of two plates, the lower and the upper. The lower plate carries the main scale and the upper plate carries verniers.

(iii) Levelling Head Assembly – It is the bottom most assembly which is screwed on the top of the tripod. It contains tribrach, foot screws and trivet.

Q.57. Describe in brief theodolite equipment along with their use.
(R.G.P.V., June 2010, Dec. 2010)

Or

What are the essential parts of theodolite ?

Ans. The following are the essential parts of a theodolite –

(i) ***Trivet*** – It is a circular plate having a central hole for fixing the theodolite on the tripod. It is also called as base plate.Three foot screws are secured to this plate.

(ii) ***Foot Screw*** – These are used for levelling the theodolite. The upper part of these are inserted into tribrach and lower part is inserted into trivet.

(iii) ***Tribrach*** – It is the triangular plate carrying three foot screws at its ends.

(iv) ***Spindles*** – The theodolite consists of two spindles or axes-one is inner and other outer. The inner axis is solid and conical and the outer is hollow.

(v) ***Lower Plate*** – It is attached to the outer axis. The scale is graduated from 0° to 360° in a clockwise direction. Each degree is subdivided into two, three or four divisions, that means one small division may be 30°, 20°, or 15° respectively.

A clamp screw and a tangent screw is also attached to the lower plate.

(vi) ***Upper Plate*** – It contains the vernier scale A and B. It is attached to the inner axis. The motion of upper plate is controlled, by the upper clamp screw and the upper tangent screw.

(vii) ***Standard or A Frame*** –Two frames shaped like the letter A are provided on the upper plate to support the telescope.

(viii) ***The Telescope*** –The telescope is provided between the standards at right angles to the horizontal axis. It can be rotated about its horizontal axis in a vertical plane.

(ix) ***Vertical Circle*** – It is fixed with the telescope and moves with it. It is divided into four quadrants. Each quadrant is graduated from 0° to 90°.

(x) ***Altitude Bubble*** – It is provided to level the instrument.

Q.58. What is theodolite ? And where is it used ? Also give its full sketch with various parts. ***(R.G.P.V., Dec. 2015)***

Ans. Refer Q.55 and Q.56.

Q.59. Differentiate between level and theodolite.
(R.G.P.V., June/July 2006)

Ans. Differences between level and theodolite are given below –

S.No.	Level	Theodolite
(i)	The instrument which is used for levelling is called as level.	The instrument which is mainly used for accurate measurement of horizontal and vertical angles up to 10′ or 20′.
(ii)	The purpose of level is to provide horizontal line of sight.	The purpose of level is to measure horizontal and vertical angles as well as to find out vertical height of an object and to findout horizontal distance between two points.
(iii)	There are following types of levels – (a) Dympy level (b) Wye level (c) Reversible level (d) Tilting level.	There are two types of theodolites namely – (a) Transit theodolite (b) Non-transit theodolite.

Q.60. Write the names of important parts of a level and a theodolite.
(R.G.P.V., June 2011)

Ans. Refer Q.42 and Q.57.

Q.61. Describe the temporary adjustment of theodolite.
(R.G.P.V., Dec. 2008)

Ans. These adjustments are carried at every set up of a theodolite before taking observations. They are as follows –

(i) Setting up of a theodolite
(ii) Levelling
(iii) Focussing and elimination of parallex.

(i) Setting up of a Theodolite – The theodolite is set up over a station. It is exactly centred over the station. It is also approximately levelled with the help of leg adjustment.

(ii) Levelling – For levelling purpose, the plate level is kept parallel to any two foot screws and the bubble is brought to centre by turning these two foot screws. Then the plate level is turned through 90° and it is brought over the third foot screw. It is levelled again. This process is repeated till the bubble remains in the centre for all the positions of the instrument. If it does not happen, then the instrument requires permanent adjustment.

(iii) Focussing and Elimination of Parallex – This is done in two stages –

(a) Focussing the Eye-piece – A piece of white paper is held in front of the telescope and the eye-piece is moved in and out until the cross-wires are clearly seen. Now, the eye-piece is focussed.

(b) Focussing the Object Glass and Elimination of Parallex – The aim of focussing the object glass is that the image should be formed in the plane of cross-wires. For this purpose, the telescope is directed towards the object and the focussing screw is turned inward or outwards until a clear and sharp image without parallex is seen. Now, the readings can be taken.

Q.62. What are the various steps of temporary adjustment of theodolite? Also explain its uses. ***(R.G.P.V., June 2016)***

Ans. Refer Q.61 and Q.55.

Q.63. What are the various permanent adjustments of a transit theodolite? Explain briefly. ***(R.G.P.V., Jan./Feb. 2008)***

Ans. The permanent adjustments of a transit theodolite are –

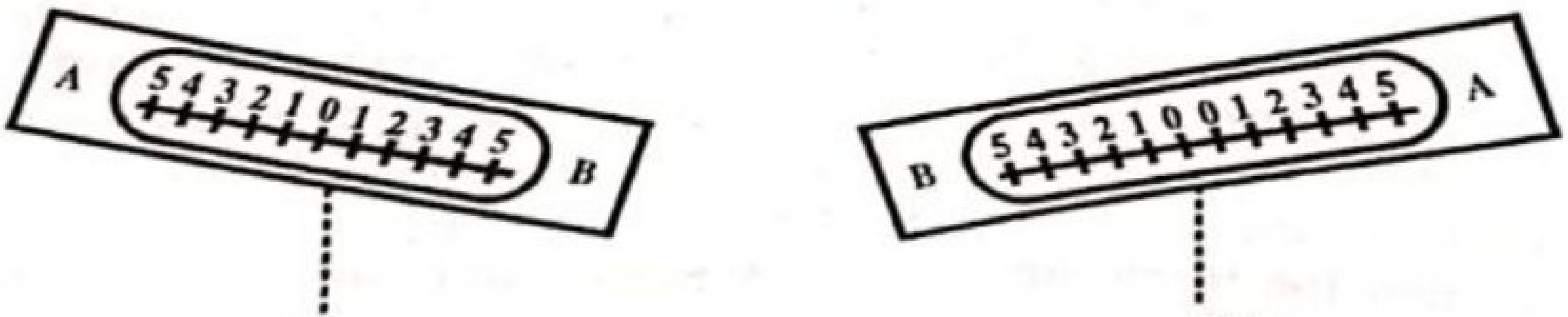
(i) Adjustment of the horizontal plate level
(ii) Adjustment of the horizontal axis
(iii) Adjustment of the telescope
(iv) Adjustment of the telescope level
(v) Adjustment of vertical circle index.

(i) Adjustment of the Horizontal Plate Level – With this adjustment the axis of the plate levels is made perpendicular to the vertical axis of the theodolite.

(a) Object – When the plate levels are in perfect adjustment, the bubbles of the plate levels must remain in the centre of their run during a complete revolution of the theodolite in azimuth.

(b) Necessity – For accurate measurement of horizontal and vertical angles, the vertical axis should remain truly vertical.

(c) Test – (1) Set up the instrument on a firm ground. Clamp the lower plate and turn the upper plate until the plate level is brought parallel to any pair of foot screws. Bring the bubble to the centre of its run by means of footscrews.



(a) *(b)*

Fig. 2.72 Two Positions of Plate Bubble

(2) Rotate the instrument about the vertical axis through 180°. The plate level is now again parallel to the same pair of foot screws but with the ends reversed in direction. If the bubble remains central, the vertical axis of the theodolite is perpendicular to the axis of the plate level (see fig. 2.72).

(d) Adjustment – (1) If the bubble does not remain central note down the reading of the bubble which is the apparent error and is twice the actual error in the axis of the plate bubble.

(2) Bring the bubble in the mean position by means of the same pair of foot-screws.

(3) Remaining half of the correction is corrected by means of the capstan headed screw provided at the end of the tube.

Repeat the test and adjustment until the bubble remains central at its run during a full revolution of the instrument in azimuth.

(ii) Adjustment of the Horizontal Axis – With this adjustment the horizontal axis is made perpendicular to the vertical axis.

(a) Object – The object of this adjustment is to ensure that the line of sight revolves at a vertical plane perpendicular to the horizontal axis.

(b) Necessity – This adjustment is very necessary for prolonging a straight line by making observations on one face only.

This adjustment can be made by the ***spire test*** as follows (see fig. 2.73).

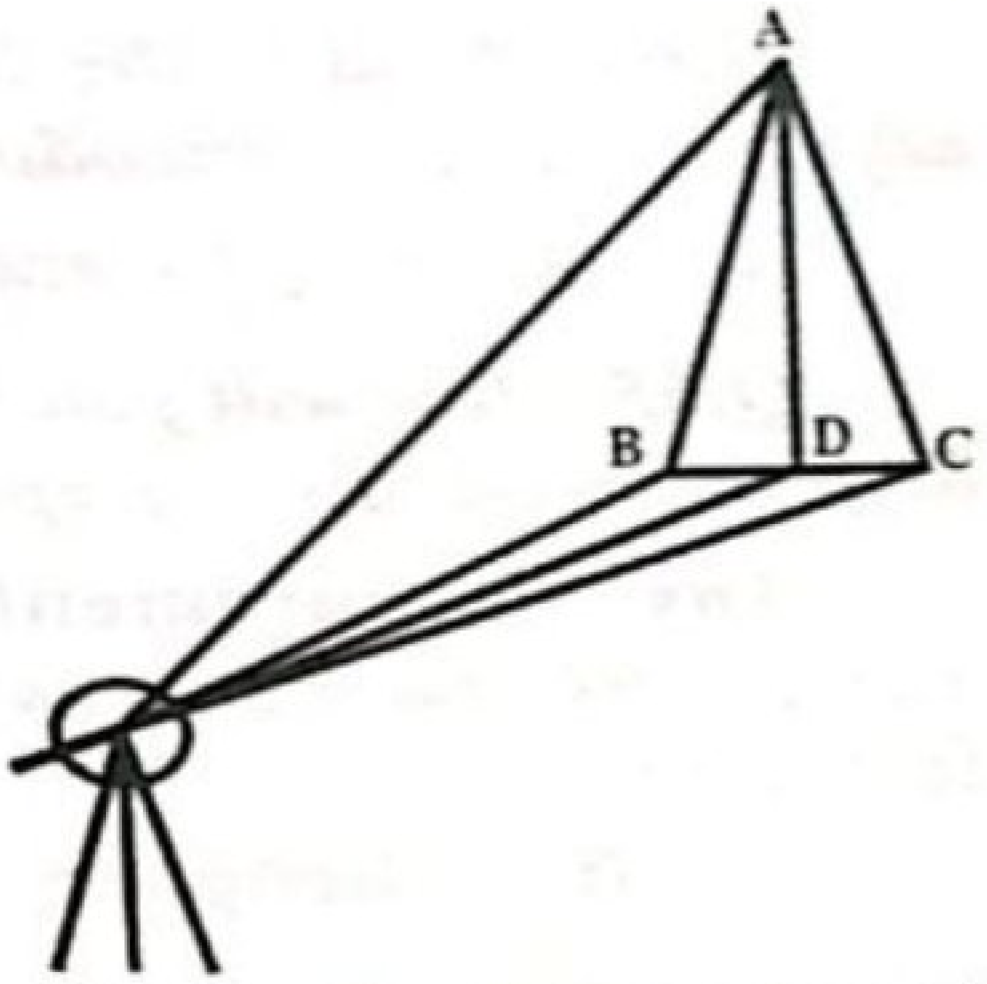


Fig. 2.73 Adjustment of Horizontal Axis by Spire Test

(c) Test – (1) Set up the instrument near a tall building on which a well defined point A is available at about 60° to 70° vertical angle.

(2) Level the instrument carefully so that vertical axis becomes truly vertical.

(3) Sight the point A and, with both the horizontal plates clamped, depress the telescope and fix a point B on the ground.

(4) Transit the telescope, swing the instrument through 180° about its vertical axis until the positions of the two supports are reversed.

(5) Bisect the point A again and depress the telescope as in step (3) above and note if the line of sight passes through B. If so, then the horizontal axis is perpendicular to the vertical axis.

(d) Adjustment – (1) If the line of sight does not pass through B, fix a point C on the line of sight close to B, on its right or left as the case may be.

(2) Locate a point D at mid-point of B and C. The point D will lie in the same vertical plane which contains the elevated point A.

(3) Sight the point D and elevate the telescope until the point A appears in the field of view.

(4) Loosen the screws of the bearing cap of the horizontal axis and raise or lower the end of the horizontal axis until the line of sight is made to pass through the point A.

Principle of the Adjustment – It may be seen that the conditions of the telescope and the horizontal axis are the same for each observation except that the positions of supports have been reversed for the second. Hence the existing discripancy is due to difference in elevations of the supports of the trunnion axis.

Q.64. What is the basic difference between temporary and permanent adjustments of a theodolite ? ***(R.G.P.V., Dec. 2013)***

Ans. Refer Q.61 and Q.63.

Q.65. How will you measure the horizontal and vertical angles with the help of theodolite ? Explain.

Ans. **Measurement of Horizontal Angle** – To measure a horizontal angle ABC between two lines AB and BC the following procedure is followed –

(i) Set up, centre and level the instrument over the ground point B.

(ii) Loosen the upper plate, set the vernier to read zero and clamp the upper plate.

(iii) Loosen the lower plate and swing the telescope until the left point A is sighted. Accurate bisection of the arrow held on station A is done by using the lower tangent screw. Read both the verniers and take the mean of the two readings.

(iv) Unclamp the upper plate and swing the telescope in clockwise direction until the point C is brought in the field of view. Tighten the upper clamp and, using the upper tangent screw, bisect the mark at C accurately.

(v) Read both the verniers and take the mean of the two readings. The difference of the means of the readings to point C and A gives the direct angle ABC.

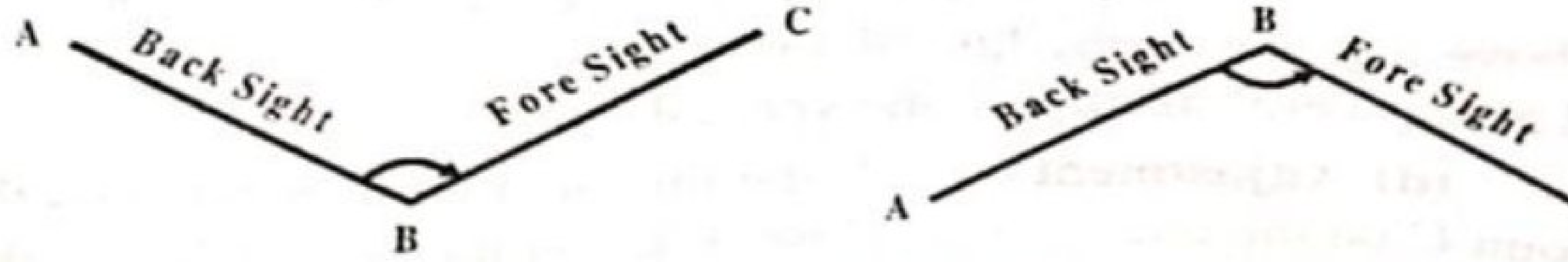


Fig. 2.74 Measurement of Horizontal Angles

(vi) Change the face of the instrument and repeat the whole process. The measure of the angle is again calculated by taking the difference of the means of the readings to point C and A on the face right.

(vii) The mean of the two measures of the angle ABC on the two faces is the required value of the angle ABC.

Measurement of Vertical Angle – A vertical angle may be defined as the angle between the inclined line of sight and the horizontal line of sight at the station in vertical plane. If the point sighted is above the horizontal axis of the theodolite, the vertical angle is known as an angle of elevation and if below, it is known as an angle of depression.

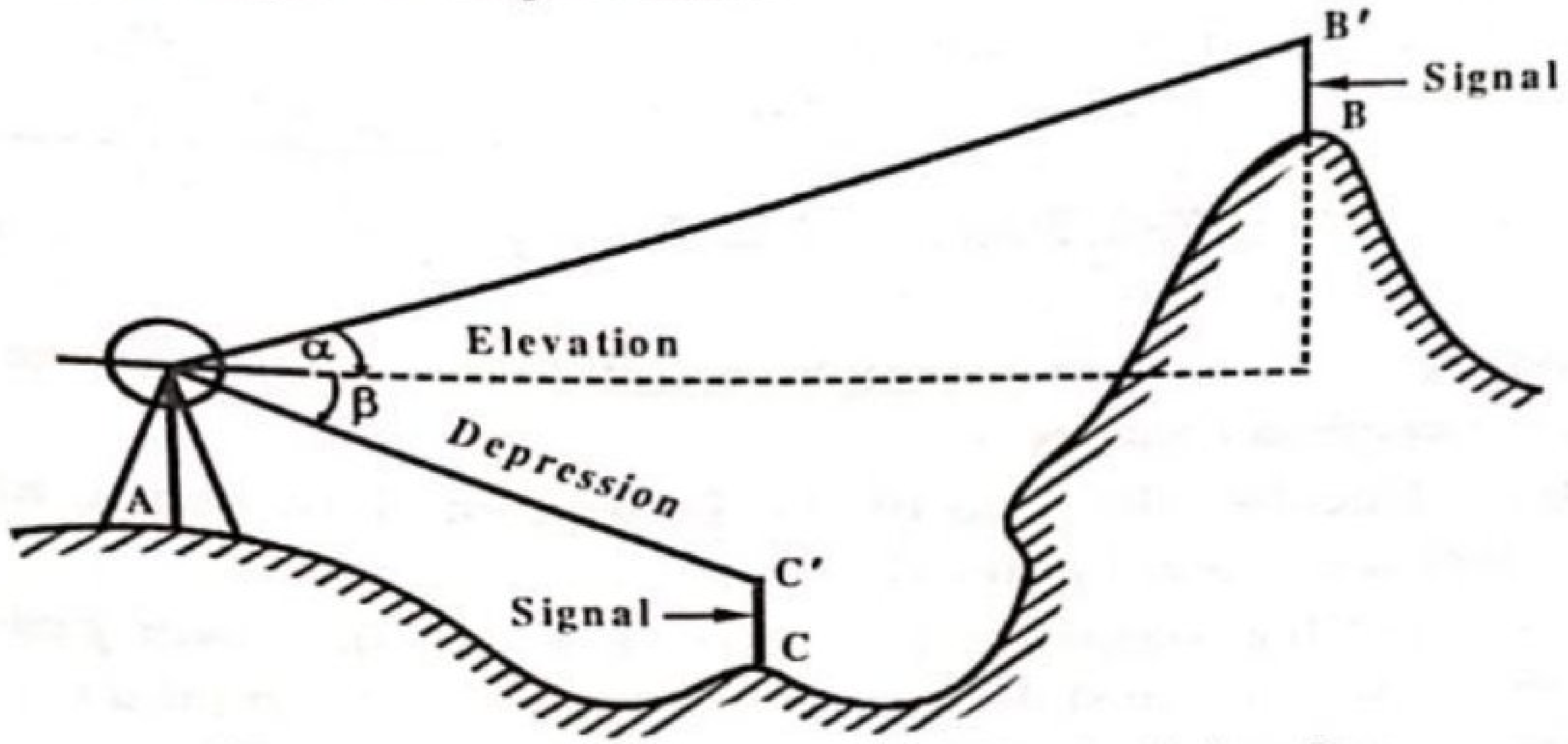


Fig. 2.75 Measurement of Vertical Angles

To measure a vertical angle subtended by station *B* at instrument station A, follow the following steps –

(i) Set up the instrument over the ground mark at station A. Level it accurately by using the altitude bubble.

(ii) Set the zero of the vertical vernier exactly in coincidence with the zero of the vertical scale using vertical clamp and vertical tangent screw. Check up whether the bubble of the altitude level is central of its run. If not, bring it to the centre of its run by means of the *clip screw*. In this position, the line of collimation of the telescope is horizontal when the vernier reads zero.

(ii) Loosen the vertical circle clamp and move the telescope in vertical plane until the station B is brought in field of view. Use vertical circle tangent screw for accurate bisection.

(iv) Read both the verniers of the vertical circle. The mean of the two vernier readings gives the value of the vertical circle.

(v) Change the face of the instrument and make the observations exactly in similar way as on the face left.

(vi) The average of the two measurement of the vertical angle will give the required value.

Q.66. Describe any two methods of measuring horizontal angle with theodolite. ***(R.G.P.V., Dec. 2012)***

Ans. Refer Q.65.

Another method of measurement of horizontal angle by the method of repetition.

Let ABC be the required angle between BA and BC, which is required to be measured by the repetition method. When the measure of an angle is small, slight error in the angle introduces a considerable error in the computed sides as the sine value of the angle changes rapidly. Therefore, for accurate and precision work, the method of repetition is generally used. In this method, the value of the angle is added several times mechanically and the accurate value of the angular measure is determined by dividing the accumulated reading by the number of repetitions.

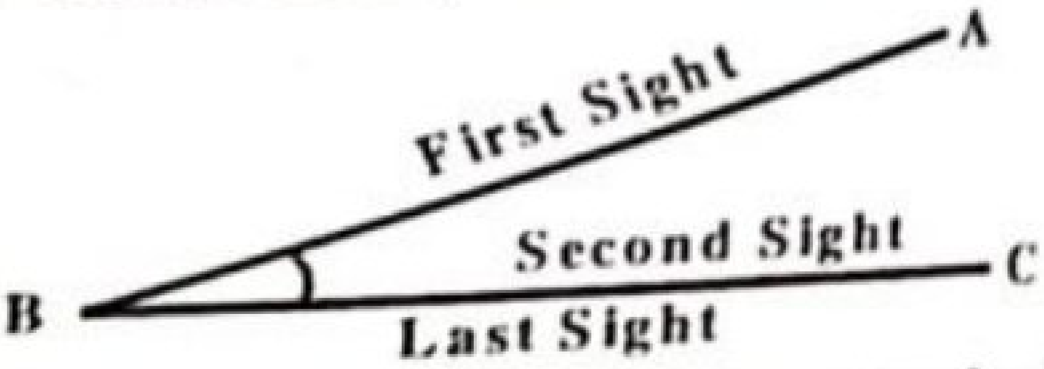


Fig. 2.76 Repetition Method

Procedure – To measure a small horizontal angle, ABC, by the method of repetition, proceed as follows –

(i) Keeping the face of the instrument left, centre and level it accurately over the ground point B.

(ii) Set the vernier to read zero. Loosen the lower plate and turn the telescope in azimuth to sight the left hand point A. Using the lower tangent screw, bisect the point exactly.

(iii) Read both the verniers and take the mean of the two readings.

(iv) Loosen the upper plate and swing the telescope in clockwise direction until point C is brought in the field of view. By using the upper tangent screw bisect the mark accurately.

(v) Read both the verniers and take the mean of the readings. The difference of the mean readings of points C and A gives the approximate value of the angle. Let it be 3° 45' 20".

(vi) Unclamp the lower plate and turn the telescope in clockwise direction until point A is again sighted. Clamp it and bisect the station mark accurately with the help of the lower tangent screw. Ensure that the vernier readings have not changed.

(vii) Loosen the upper plate and turn the telescope in clockwise direction and again bisect the point C exactly by using the upper tangent screw. The verniers will now read double the value of the angle ABC.

(viii) Repeat the process until the angle is repeated the required number of times, say 5.

(ix) Read both the verniers. The final reading after 5 repetitions should be approximately equal to 5 times of the approximate value of the angle. In this case, say 5 × (3° 45' 20") + index error if any. Take the mean of the two vernier readings.

(x) The accumulated angle is obtained by taking the difference of the two mean readings to stations C and A.

(xi) Divide the accumulated angle by the number of repetitions (in this case 5) to get the correct value of the angle ABC.

(xii) Change the face of the instrument and repeat the whole procedure in exactly the same way, as before and obtain the correct value of the angle ABC on face right.

(xiii) The mean of the two values of the angles obtained on face left and on the face right gives the required value of the angle ABC.

PLANE TABLES AND RELATED DEVICES

Q.67. What do you understand by plane table surveying ?

(R.G.P.V., June 2016)

Ans. The plane table is an instrument used for surveying by a graphical method in which the field work and plotting are done simultaneously. The main advantage of plane table surveying is that the topographic features to be mapped are in full view. It is most suitable for small and medium scale mapping. It can also be used to tie topography by existing control and to carry its own control system by triangulation or traverse and by lines of levels.

The principle of plane tabling is that the lines joining the points on the plane table are made parallel to their corrsponding lines joining the ground points. In this method, the map is plotted at the same time as the field work progresses. The method derives its name from its equipment which is in the form of a plane table or drawing board.

Q.68. What are the advantages and disadvantages of plane table surveying ?

(R.G.P.V., Dec. 2014)

Ans. **Advantages of Plane Table Survey –**

(i) The observations and plotting are done simultaneously. Hence, there is no risk of omitting necessary details.

(ii) The errors and mistakes in plotting can be checked by drawing check lines.

(iii) Irregular objects can be plotted accurately as the lay of land in view.

(iv) It is most rapid and useful for filling in details.

(v) No great skill is required.

(vi) It is less costly than theodolite survey.

(vii) Advantages in magnetic area where compass survey is not reliable.

Disadvantages of Plane Table Survey –

(i) It is not suitable for work in a wet climate and in a densley wooded country.

(ii) The absence of measurements are inconvenient, if the survey is to be replotted to some other scale.

(iii) It is heavy and awkward, to carry and the accessories are likely to be lost.

(iv) It does not give accurate results.

***Q.69. Describe in brief plane table equipments along with their use.* (R.G.P.V., Dec. 2010)**

Ans. The instruments required to carry out the plane table survey are as follows –

(i) Plane table
(ii) Alidade
(iii) Spirit level
(iv) Magnetic compass
(v) Drawing paper.

(i) Plane Table – It consist of board, 750 × 600 mm and about 25 mm thick. It is mounted on a tripod.

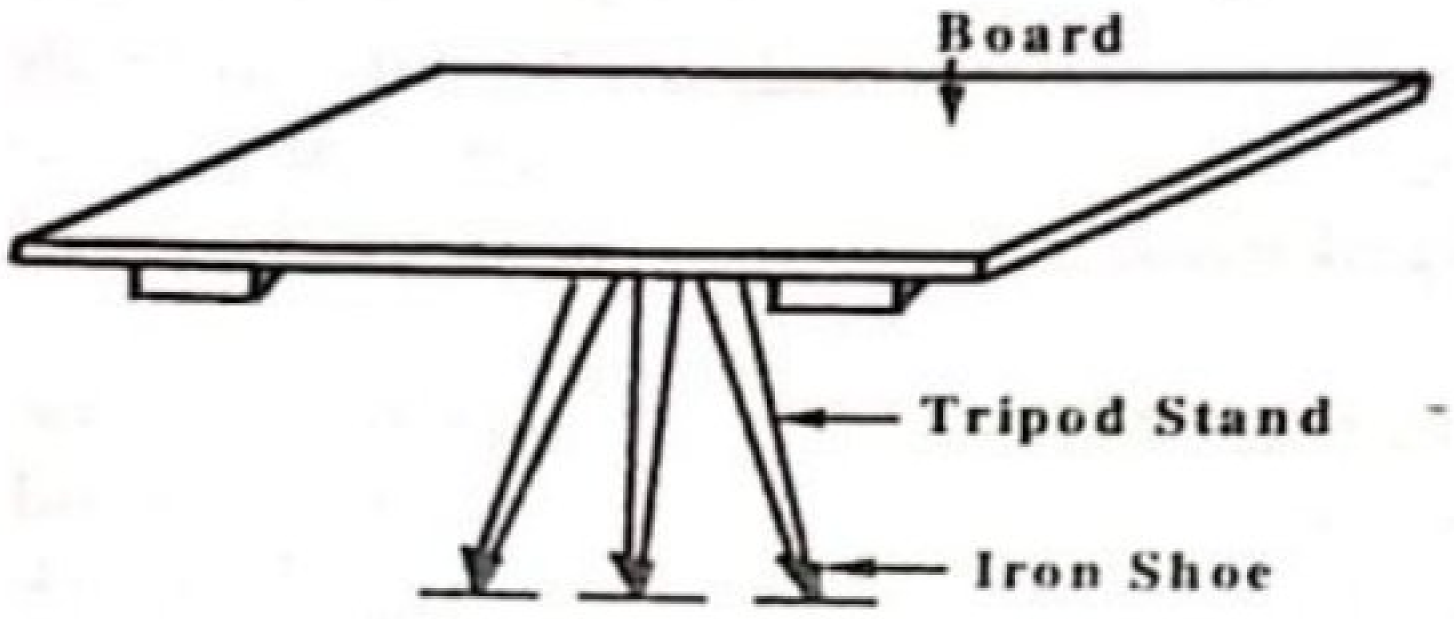


Fig. 2.77 Plane Table

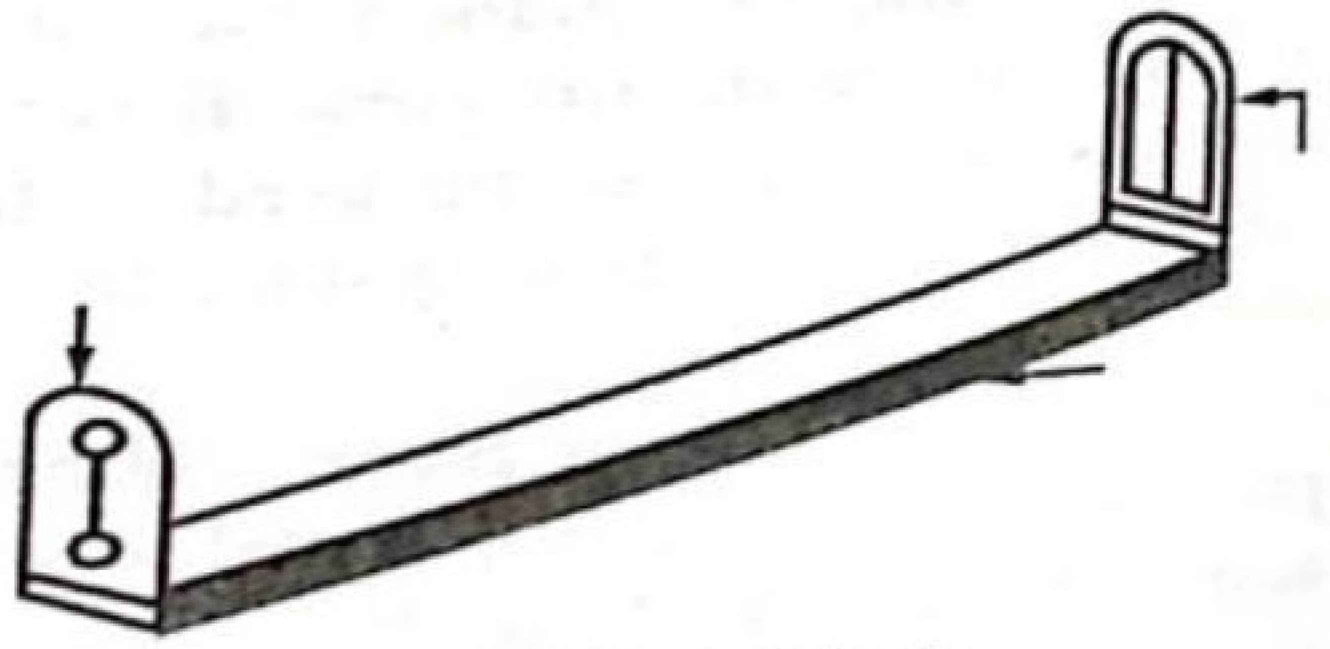


Fig. 2.78 Alidade

(ii) Alidade –This is the instrument, about 45 cm long which is used on the plane table for taking sights. It is made up of metal or wood.

(iii) Spirit Level – It is a small metal tube containing a small bubble of spirit. It is used for levelling the plane table.

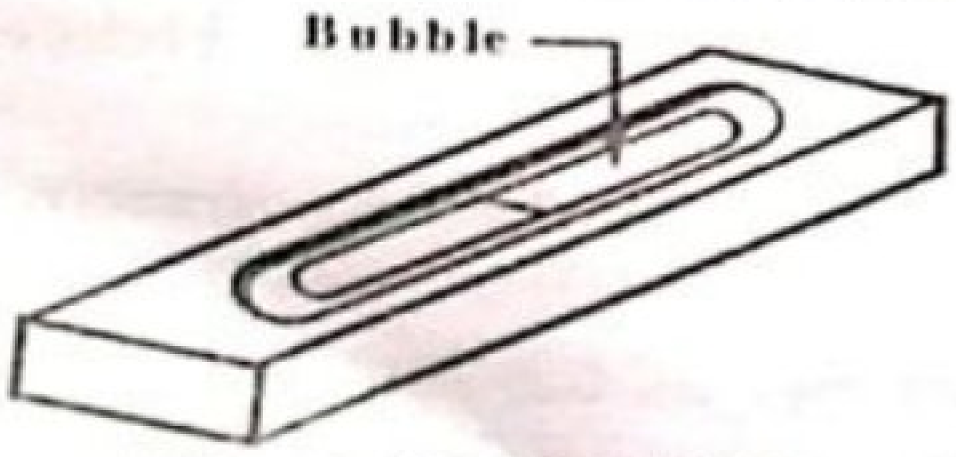


Fig. 2.79 Spirit Level

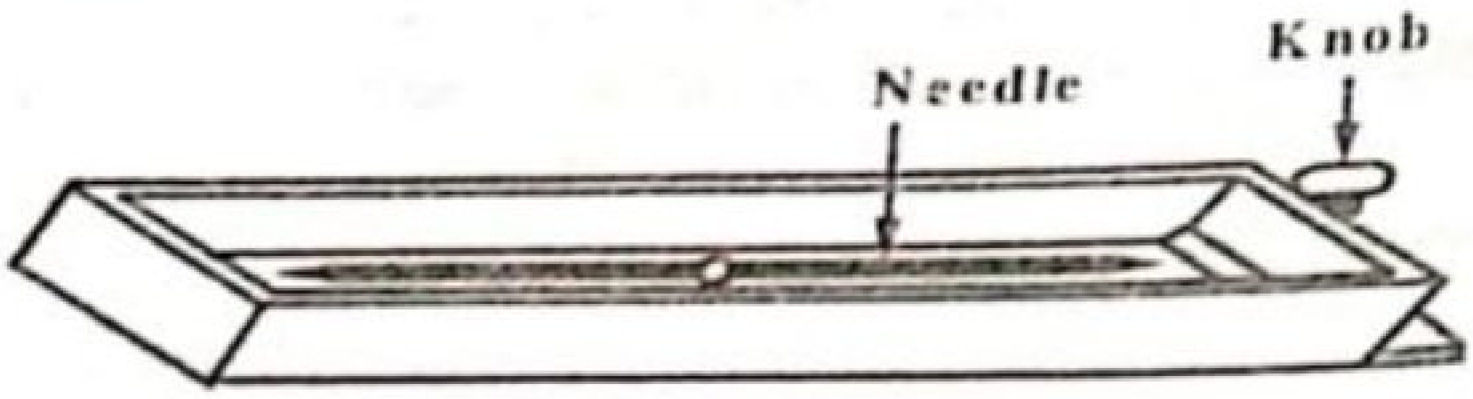


Fig. 2.80 Compass

(iv) Compass – It is made up of rectangular box of non-magnetic metal. It is used to mark the north direction on the map.

(v) U Fork or Plumbing Fork With Plumb Bob – It is a metal strip bent in the shape of a U having equal arm lengths. The top arm is pointed and the bottom arm carries a hook for suspending a plumb bob. It is used for centering the table over a station.

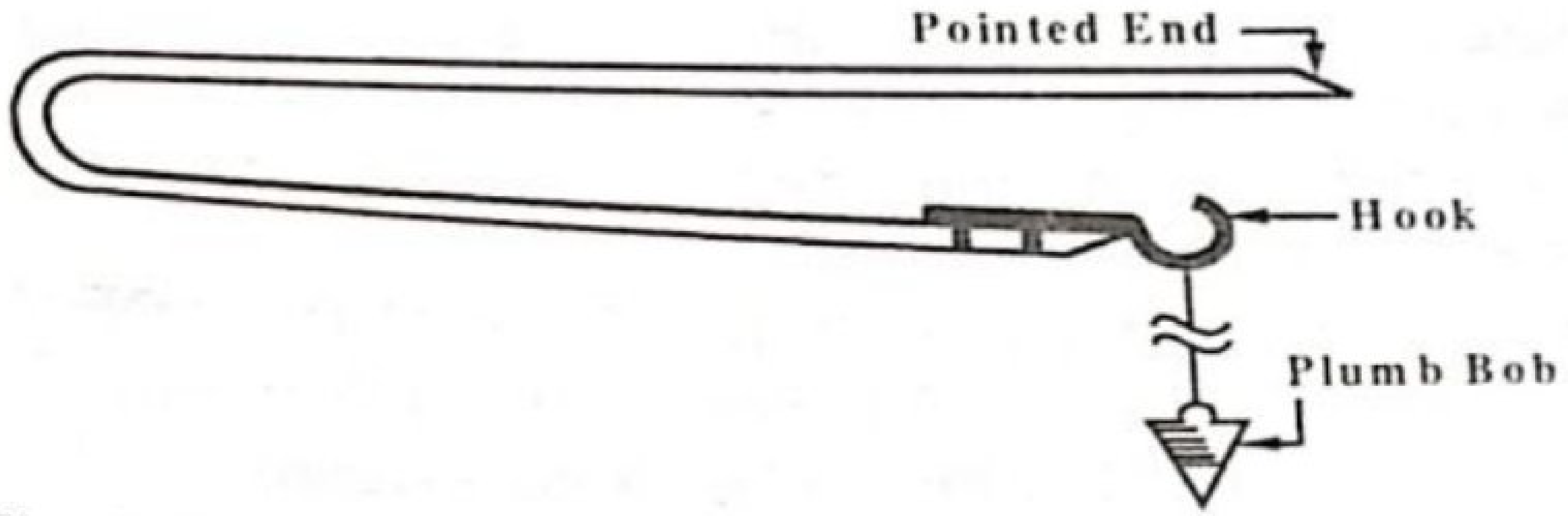


Fig. 2.81 U Fork or Plumbing Fork With Plumb Bob

Q.70. Discuss about the merits and demerits of plane table surveying. Also enumerate various accessories used in plane table surveying.

(R.G.P.V., Dec. 2011)

Ans. Refer to Q.68 and Q.69.

Q.71. What are the different operations involved in plane tabling ? Explain orientation of plane table in detail. *(R.G.P.V., June 2005, Jan./Feb. 2007)*

Or

Describe the plane table survey. *(R.G.P.V., June 2010)*

Ans. Generally three operations are needed –

(i) Fixing the table to the tripod.

(ii) Setting –

(a) Levelling the table (b) Centring (c) Orientation.

(iii) Sighting the points.

(i) The plane table will be fixed on the tripod stand.

(ii) Setting – Setting of instrument consist following stages –

(a) Levelling – It is the operation of bringing the plane table in a horizontal plane. Set the plane table at a convenient height, by spreading the legs. Level the board with the help of a spirit level.

(b) Centring – It is the operation of bringing the plotted station point exactly over the ground station to achieve this, the pointed leg of the plumbing fork is placed against the plotted point and the plumb bob is suspended from its other leg. Exact centring is important for large scale mapping only. For small scale mapping, an error on centring of 30 cm is permissible.

(c) Orientation – Orientation is the process of placing the plane-table into some fixed direction so that line representating a certain direction on the plane is parallel to that direction on ground. This is essential condition to be fulfilled when more than one instrument station is to be used. If orientation is not done, the table will not be parallel to itself at different positions result, in an overall distortion of the map.

The processes of centring and orientation are dependent on each other. For orientation, the table will have to be rotated about its vertical axis, thus disturbing the centring. If precise work required then the plotted point should be exactly over the ground point repeated orientation and shifting of the whole table are necessary.

There are two main methods of orienting the plane table –

(1) Orientation by means of through compass

(2) Orientation by means of backsighting.

(1) Orientation by means of Through Compass – The through compass is placed on the top right corner of the plane table in such a way that the magnetic needle points exactly towards the N-S direction. Draw this line along the edge of the compass shift and setup the plane table on the next station.

Place the through compass along the N-S line rotate the table till the magnetic needle coincides with N-S line drawn previously. This is a crude (approximate) method of orientation and cannot be employed at station where local attraction is suspected.

The following are the conditions in which this method is accepted (employed) –

(A) When speed is more important than accuracy.

(B) When there is no second point available for orientation.

(C) When the traverse is so long that accumulated errors in carrying the azimuth forward might be greater than orientation by compass.

(D) For approximate orientation prior to final adjustment.

(E) In certain resection problems.

(2) Orientation by means of Backsighting – This is the most accurate method of orientation. The plane table is set on a new station and the alidade is placed against the line joining the two stations. The table is rotated until the line of sight bisects the previous station.

***(iii) Sighting the Points* –** Once the table has been set, the points to be located are sight through alidade. The alidade is kept pivoted about the plotted location of the instrument station and is turned so that the line of sight passes or bisects the signal at the point to be plotted. A ray is then drawn from the instrument station along the edge of the alidade. Similarly the rays to other points to be sighted are drawn. The points are finally plotted on the corresponding rays, either by way of intersection or by radiation.

Q.72. Differentiate between compass survey and plane table survey. ***(R.G.P.V. June/July 2006)***

Ans. Differences between compass and plane table survey are given below –

S.No.	***Compass Survey***	***Plane Table Survey***
(i)	The branch of surveying in which directions of survey lines are determined by a compass and their lengths by chaining or taping is called as compass surveying.	The plane table is an instalment used for surveying by a graphical method in which the field work and plotting are done simultaneously.
(ii)	It is suitable for large mapping.	It is suitable for small and medium scale mapping.
(iii)	In this topographical features of terrain are not clear.	In this topographical features to be mapped are in full view.
(iv)	It is not more suitable for topographical survey.	It is suitable for topographical survey.
(v)	It consumes more time in survey and its mapping.	It consumes less time in survey and its mapping.

Q.73. What are the various methods of plane table surveying ? Explain any two in detail. ***(R.G.P.V., Dec. 2012)***

Or

State various methods of plane table surveying. Explain any one method in detail. ***(R.G.P.V., June 2013)***

Or

What are the different methods of plane tabling ? Describe the one of them fully with neat sketches. ***(R.G.P.V., Dec. 2013)***

Or

What are the various methods of plane table survey ? Explain intersection method with the help of neat sketch.
[R.G.P.V., June 2007, 2008(N), Feb. 2010]

Ans. There are four methods of plane table surveying –

(i) Radiation
(ii) Intersection] → used for locating the details.

(iii) Traversing
(iv) Resection] → used for locating the plane table station.

(i) Radiation – In this method the instrument is setup at a station and rays are drawing to various stations, which are to be plotted. The distances are cut to a suitable scale after actual measurements.

(a) Select a station O such that all the other stations A,B,C and D are accessible and visible from O.

(b) Set up the table at O, transfer the point on to the sheet by means of plumbing ports. Clamp the table.

(c) Place the alidade touching to O and sight to A. Draw the ray along the riducial edge of the alidade. Similarly draw the rays for B, C, D also.

(d) Measure OA, OB, OC, OD with tape or chain and plot it to some scale on corresponding ray.

(e) Join all points marked on sheet which give the closed area.

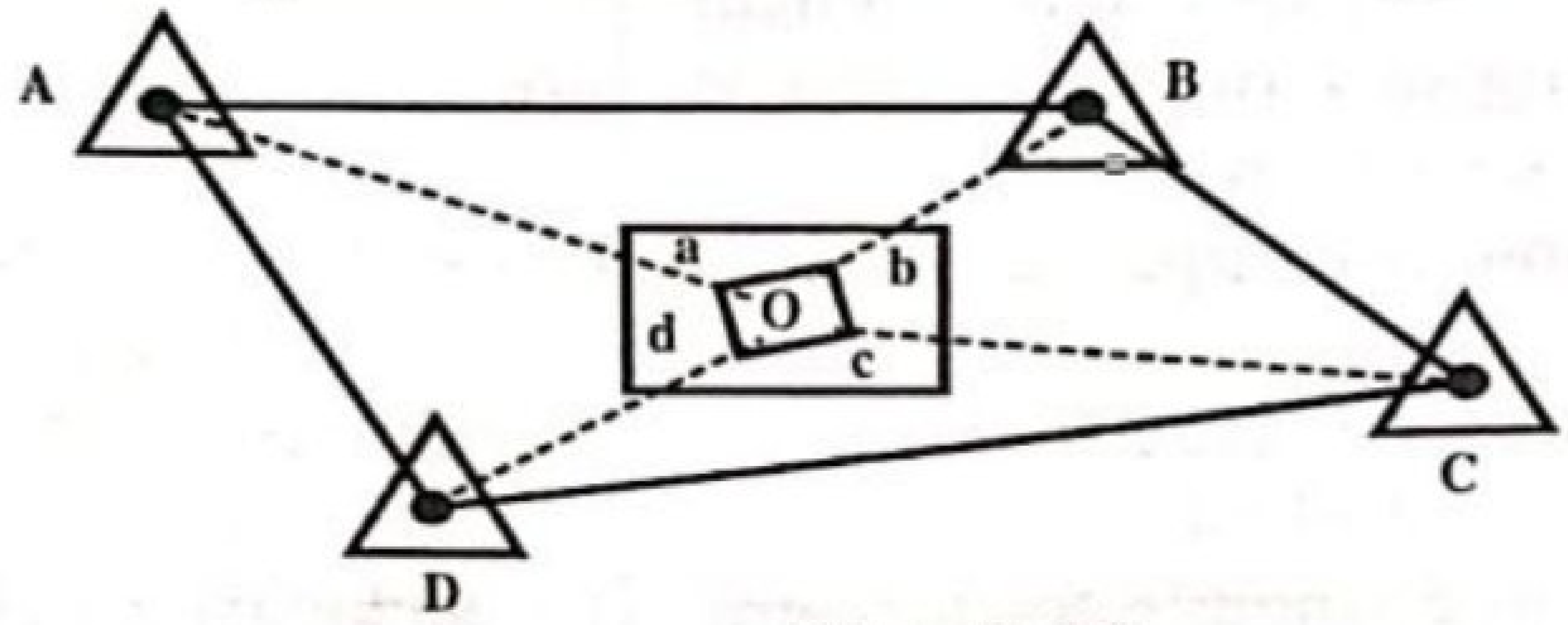


Fig. 2.82

Suitability – This method is suitable only when the area to be surveyed is small and all the stations are visible and accessible from the instrument station. The scope of the method is increased when the distance are measured by the tachometer.

(ii) Intersection – In this method, two stations are so selected that all the other stations to be plotted are visible from those. The line joining these two stations is called base line. The length of this line is measured very accurately. Rays are drawn from these stations to the stations to be plotted. The intersection of the rays from the two stations gives the position of the stations to be plotted on the drawing sheet. Sometimes this method is also termed as graphical triangulation.

Let A and B be the two accessible stations, such that A and B can be suitably plotted. 'C' is the station to be plotted by intersection. Place the table at A. Set up it. Plot N-S direction. Transfer ground station A as 'a' on drawing sheet with the alidade, centred at a sight B. Draw a ray AB and cut 'ab' to a suitable scale, with the alidade at a sight c also and draw a ray 'ac', shift the table to B and set up place the alidade at 'b' and sight 'c' draw ray 'bc'. The intersection of the two rays gives the position of station 'c' as 'c' on the plane table.

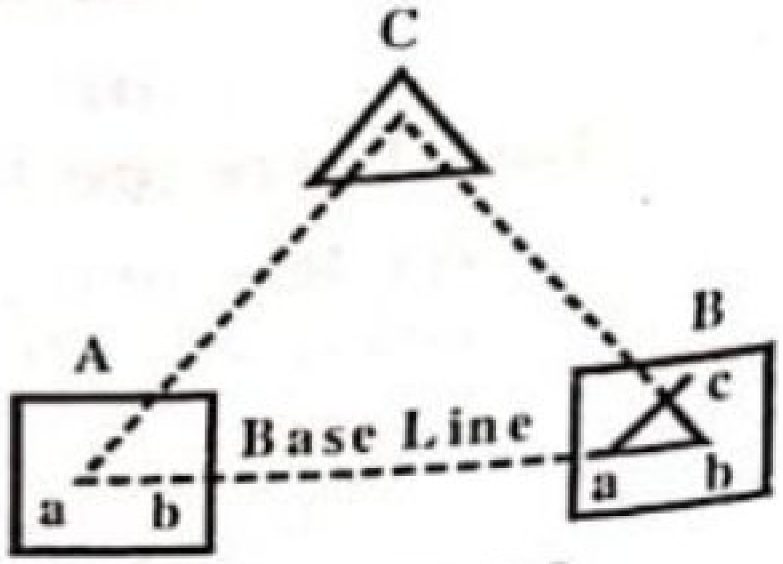


Fig. 2.83

Suitability – This method is very commonly used for plotting details. It is preferred when the distance between the stations is too large, or the stations, are inaccessible or the ground undulating. The most suitable examples of broken boundaries which can be very conveniently plotted by this method.

Q.74. Explain step by step procedure of method of traversing of plane-table surveying. Also discuss about the checks applied. (R.G.P.V., June 2012)

Or

Explain how plotting can be done by plane table surveying using method of traversing. Mention step by step procedure. (R.G.P.V., June 2014)

Ans. The method of traversing by a plane table is similar to that of compass or theodolite traverses. At each successive station, the plane table is set, a foresight is taken to the following station and its location is plotted on the foresight by measuring the distance directly between the two stations. Sometimes a resector is drawn from the location of a well fixed point to intersect the foresight at good angle, to get the location of the following station, thus avoiding the measurement of the distance.

Principle of the Method – Refer fig. 2.84.

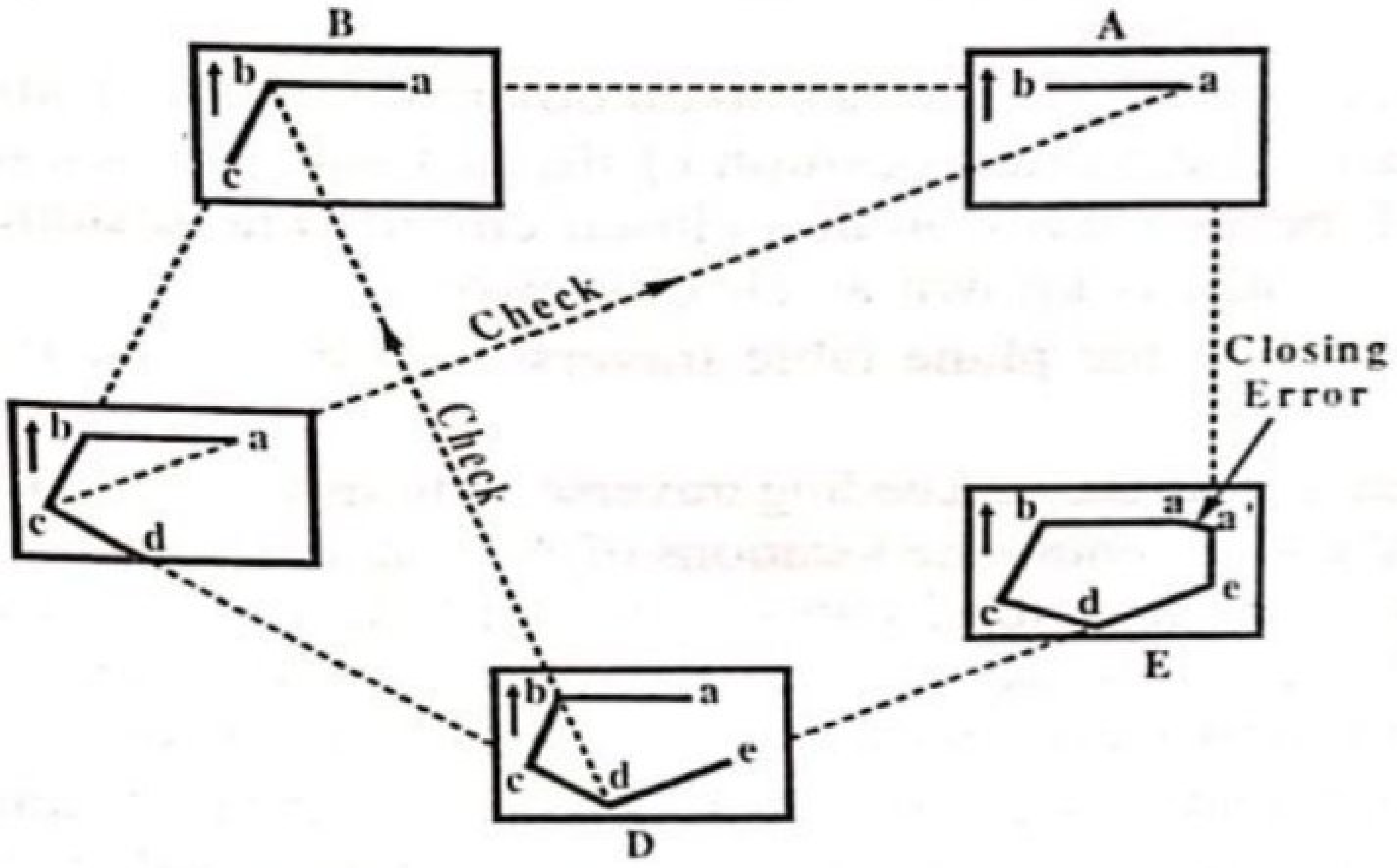


Fig. 2.84 A Plane Table Traverse

The principle of traversing is similar to that of radiation method. The only difference is that in the case of radiation, the observations are made to locate all the points in the neighbourhood of a station where as in traversing the observations are made only to such points which will subsequently be occupied by the surveyor for locating the details. Plane table traversing is always carried out in closed circuits or is originated from, and closed on fixed points or other resected point.

Procedure – The plane table traverse is carried out as follows –

(i) Recognize the area to be surveyed to select the number of stations, sufficiently far apart, ascertaining their intervisibility and feasibility of chaining.

(ii) Set up the plane table over the starting station A and transfer the point with a U fork on the sheet.

(iii) Orient the plane table approximately so that the area to be surveyed falls on the table.

(iv) Draw a magnetic north line with a trough compass.

(v) With the alidade pivoted at 'a' sight the following station B, and draw a ray along the fiducial edge of the alidade and also its extremeties are marked on both edges of the table.

(vi) Measure the distance AB accurately and plot it on the scale of survey.

(vii) Shift the table to station B, centre the table such that the ray ab passes a point vertically above the ground point B.

(viii) Place the alidade along the ray ba and rotate the table till A is sighted clamp it.

(ix) Pivoting the alidade about b, sight C. Measure BC and plot it on the ray drawn towards C.

Similarly, the plane table is set up on other succeeding stations till the last station is plotted. The plotted position of the last station should coincide with the plotting of the first position in a closed circuit. The distance between the two positions, if any, is known as closing error.

Closing error of the plane table traverse can be adjusted graphically as follows –

Let abcdea' denote the succeeding traverse stations whose starting and closing station is A. 'a' and a' denote the locations of A as obtained by traversing. In case the traverse was errorless, the location a' would have coincided with its plotted position 'a'. The distance aa' which is known as closing error is to be adjusted such that error is distributed equally without disturbing the shape of the traverse.

Lay out a straight line parallel to longer edge of the table and mark on it a, b, c, d, e and a' at their respective distances from each other on the scale of the survey or on any other convenient scale.

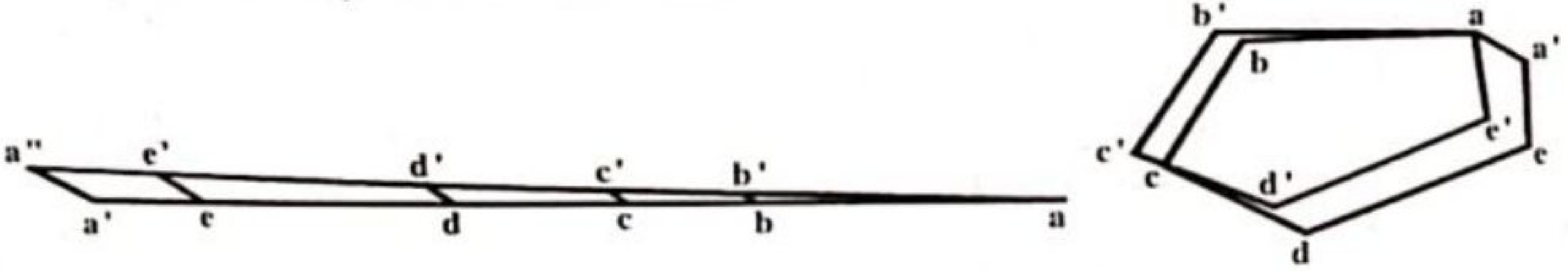


Fig. 2.85 Graphical Adjustment of Traverse

At a', draw a', a" parallel and equal to the length of the closing error. Join aa" and draw parallel line through points b, c, d, and e to meet the line aa" at b', c', d', and e'. Join aa' on the traverse and draw lines parallels to aa" through traverse points b, c, d, and e. On these parallels mark off bb', cc', dd', etc. equal to the distances bb', cc', dd', ... Join a, b, c, d, e and a to represent the adjusted traverse.

ELECTRONIC SURVEYING INSTRUMENTS ETC. MEASUREMENT OF DISTANCES–CONVENTIONAL AND EDM METHODS, MEASUREMENT OF DIRECTIONS BY DIFFERENT METHODS, MEASUREMENT OF ELEVATIONS BY DIFFERENT METHODS, RECIPROCAL LEVELLING

Q.75. What do you understand by the term EDM ?

(R.G.P.V., June 2016)

Ans. EDM is a general term embracing the measurement of distance using electronic method. It is based upon the measurement of phase difference between received and transmitted signals. Hence, this method also based on propagation, generation, reflection and subsequent reception of electromagnetic waves. A measuring wave is generated and put on a carrier wave for transmission. In the vacuum, electromagnetic waves of all frequencies travel at same speed. The range of wavelength which is used in EDM varies from 30 m to 400 nm. If the wave/length uses in shorter, they are accurate but their penetration is less, as in electro optical instruments.

Q.76. Explain the principle of electronic distance measurement.

(R.G.P.V., June 2015)

Ans. As shown in fig. 2.86, assume D is the horizontal distance between the two stations. With the help of two waves of different frequencies f_1 and f_2, the distance D can be computed as

$$D = nx_1 + y_1$$
$$= nx_2 + y_2$$

where n = Number of measuring units x_1 and x_2

y_1 and y_2 = Phase shifts

The two frequencies are so selected that

$$mx_1 = (m + 1)x_2$$

Thus,
$$x_1 = (m + 1)x_2/m$$

and
$$D = n(m + 1)\, x_2/m + y_1$$
$$= nx_2 + y_2$$

From which

$$D = (m + 1)(y_2 - y_1) + y_1$$

The distance is collected independently of n, the number of entire units in the measurement. A delay-null method computed y_1 and y_2 electronically. The distance will be computed without ambiguity only up to a certain value. With the help of simple calculation y_1 and y_2 can be converted into distance. If $m = 10$, then $10\, x_1 = 11\, x_2$. The distance can be computed specially to a small value only with the help of the two frequencies given below.

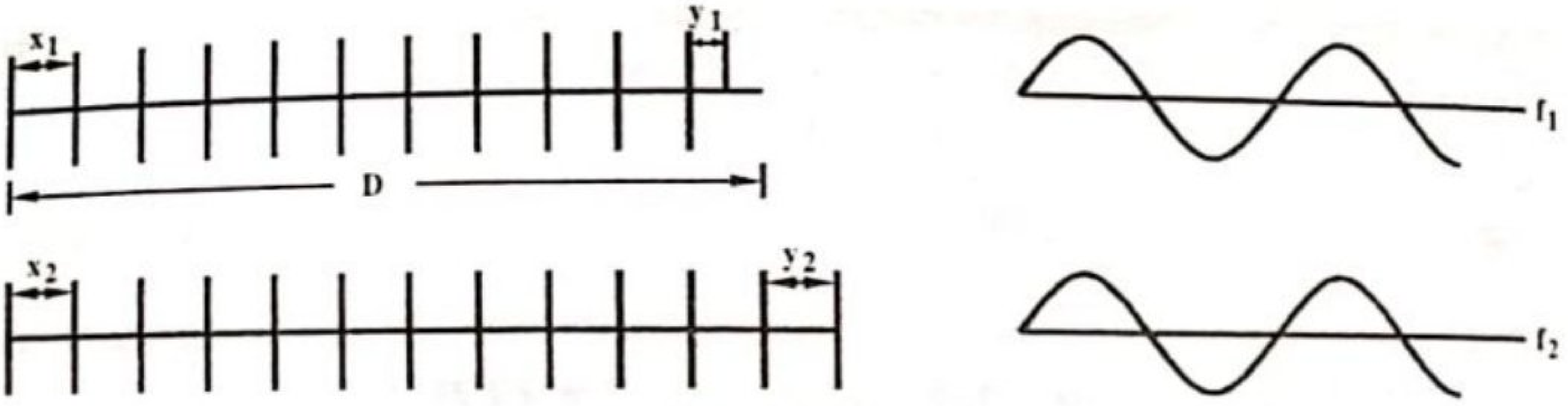


Fig. 2.86

Assume $y_1 = 0.4$ m and $y_2 = 1.0$ m.

Then, $D = (10 + 1)(1.0 - 0.4) + 0.4 = 7$ m, $n = 7$. With the help of two given wave patterns, the distance up to 11 m can be computed. The same phase difference of $1.0 - 0.4 = 0.6$ will be repeated for distance of $11 + 7$, $11 + 2 \times 7$, etc. A third frequency can be added like $100x_2 = 101\ x_3$, which will increase the limit beyond 100 m.

The same value of the difference $(y_2 - y_1)$ will be corrected for other distances as well. A number of wave patterns are used for computation, in order to increase the range and eliminate ambiguity. Thus we have devices with small ranges of about 3 – 150 km. Thus a device may use a number of frequencies like 10, 9.99, 9.9, 9 MHz. With the help of these frequencies, three different ranges can be obtained.

Q.77. How EDM methods are better than conventional method ?
(R.G.P.V., June 2004, 2005, April 2009)

Ans. EDM methods are better than conventional method as discussed below –

(i) The surveyor does not need to walk the distance.

(ii) Water, rough terrain and trees are the obstacles. The distance can be taken across these obstacles.

(iii) Instruments which can download the data into a electronic field book, data logger or computer can be purchased. Therefore, the errors of manually recording data can be eliminated.

(iv) EDM instruments can generate a reading every few seconds after once leveled.

(v) For taking measurements EDMs need fewer individuals.

(vi) EDMs will take reading of small and large distances.

(vii) EMDs instruments easily take readings of line which are difficult of access, like highways, standing from crops, across rivers and lakes, etc.

(viii) The EDMs instruments take time in minutes for get the accurate distance while distances of several miles.

(ix) Two skilled workers can do the work faster and better compared to a four regular worker crew.

Q.78. Explain EDM method. ***(R.G.P.V., June 2013)***

Or

Write short note on – EDM methods.

(R.G.P.V., June/July 2006, Dec. 2006, Nov/Dec. 2007)

Or

Explain the EDM method in detail. ***(R.G.P.V., Dec. 2012)***

Or

Write short note on EDM method. ***(R.G.P.V., Dec. 2016)***

Ans. EDM methods are the methods by which we are able to find out the distances, directions and elevations with the help of electronic instruments like electronic distance meter, Geodimeter, Tellurometer, Distomat, electronic theodolite and electronic planimeter.

By these methods we are able to find out the much accurate and correct measurements and observations. These methods provide much accuracy and precision than conventional methods.

There are various electronic surveying instruments used for precision work –

(i) ***Electronic Distance Meter*** – Earlier we have seen the engineering works/situations where accurate measurement of distance becomes absolutely necessary. Similarly direct measurement of distance becomes very difficult when the terrain is very rough such as valleys or steep hills. Electronic distance meters have been developed which give an accuracy of 1 in 10^5 for ranges upto 50 km. These ED meters work on external source of power i.e., Ni-Cd battery of specified voltage.

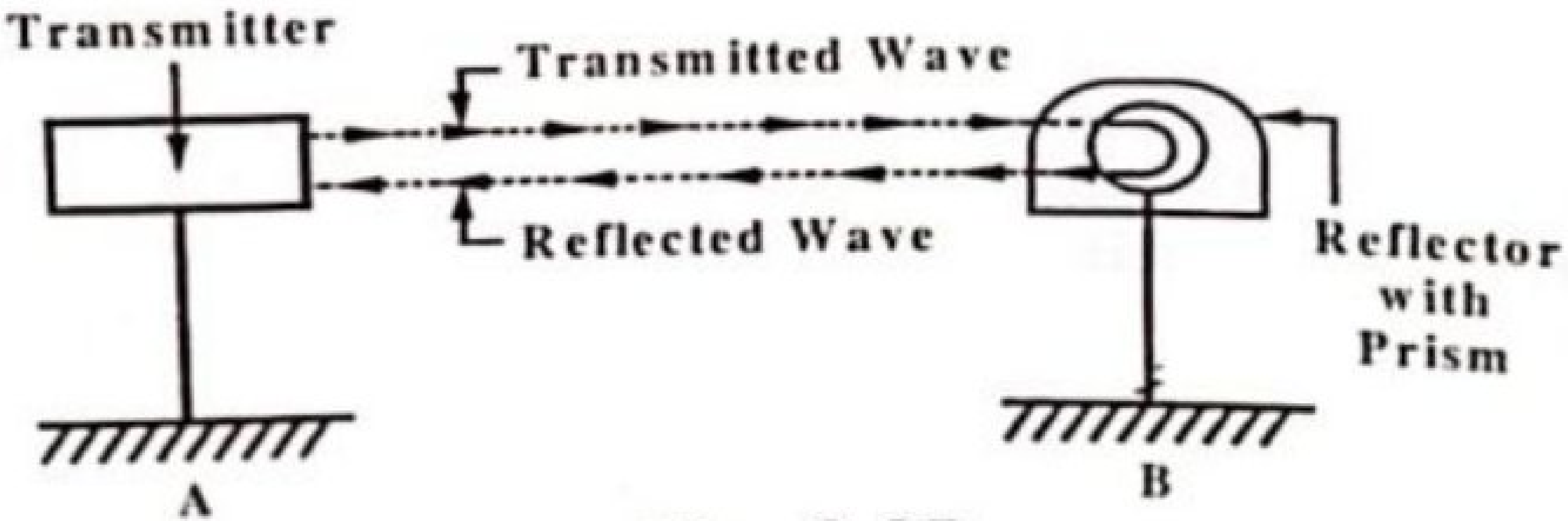


Fig. 2.87

Basic Principle – Suppose the distance between A and B is to be measured. A wave is transmitted from the transmitter at station A with certain phase angle. There is a reflector with prisms at the other end 'B'. The wave strikes the reflector and is reflected from B and received back at the transmitter end at 'A' with different phase angle. By electronic circuitry at A, the phase difference between the transmitted wave and reflected wave is measured and converted into distance. The wave used for measurement of distance is called measuring wave.

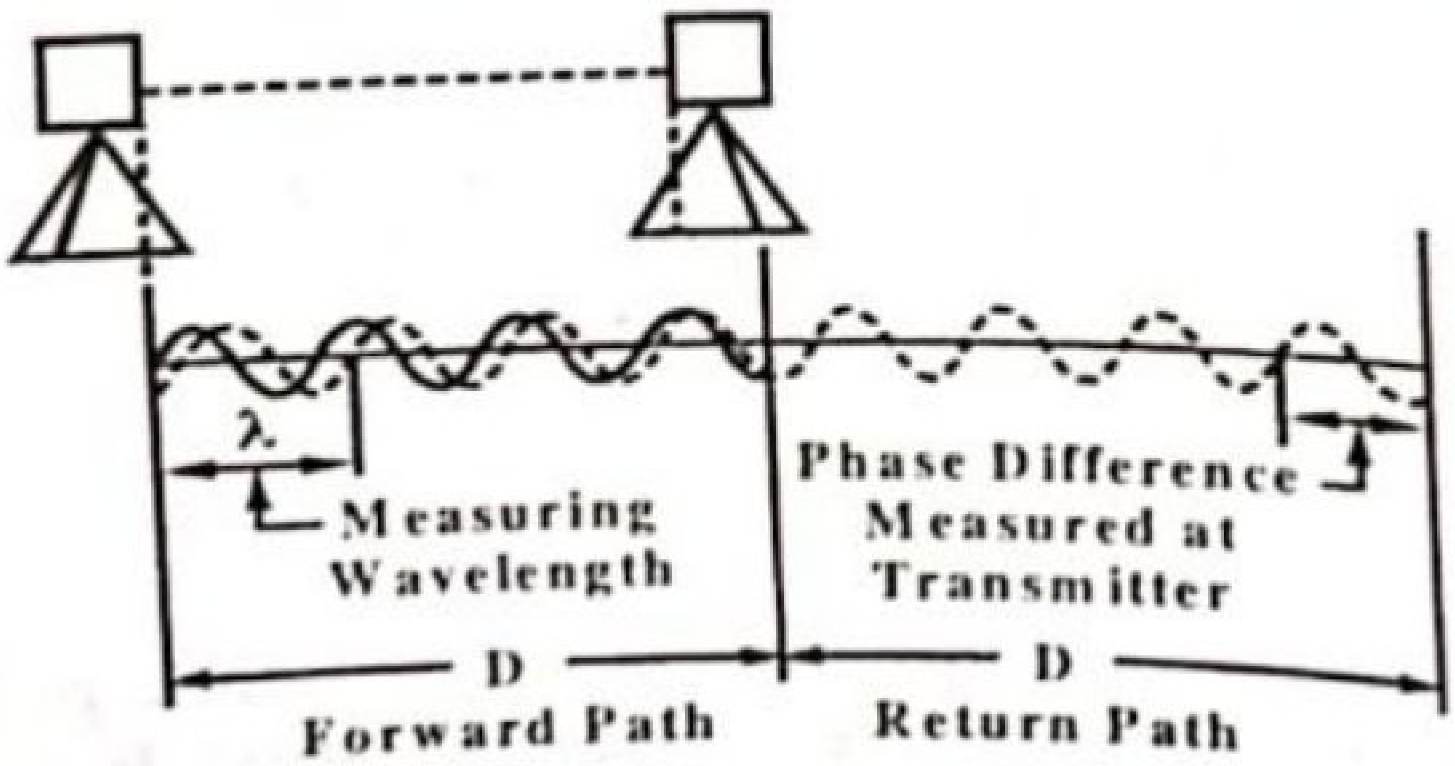


Fig. 2.88

Principle of Phase Comparison – Difference in phase between the transmitted and reflected waves represents the fraction of wavelength by which the double length line exceeds an integral number of complete wavelengths. Null method is used to measure the phase difference. For this, an electronic circuit called as delay line is interposed so as to delay the wave till there is no phase difference between the emitted and received signals.

(ii) Geodimeter – This instrument is based on the principle of the propagation of modulated light waves. The geodimeter can be used in light or at day time. The range of this instrument is vary from 15 m to 15 km. Fig. 2.89 shows the schematic diagram of the geodimeter.

The main instrument is placed at one end of the line to be measured. A reflector is placed at the other end of the line. The light in the form of a narrow beam is focussed from the geodimeter to the reflector. The light is reflected back to the photo multiplier of the instrument. The variation in the intensity of this reflected light causes the current from the photo multiplier to vary where the current is already being varied by the direct signal from the crystal controlled oscillator. The distance between the geodimeter and the reflector i.e. length of the line, is derived from the phase difference between the two pulses recieved by the cell of the instrument.

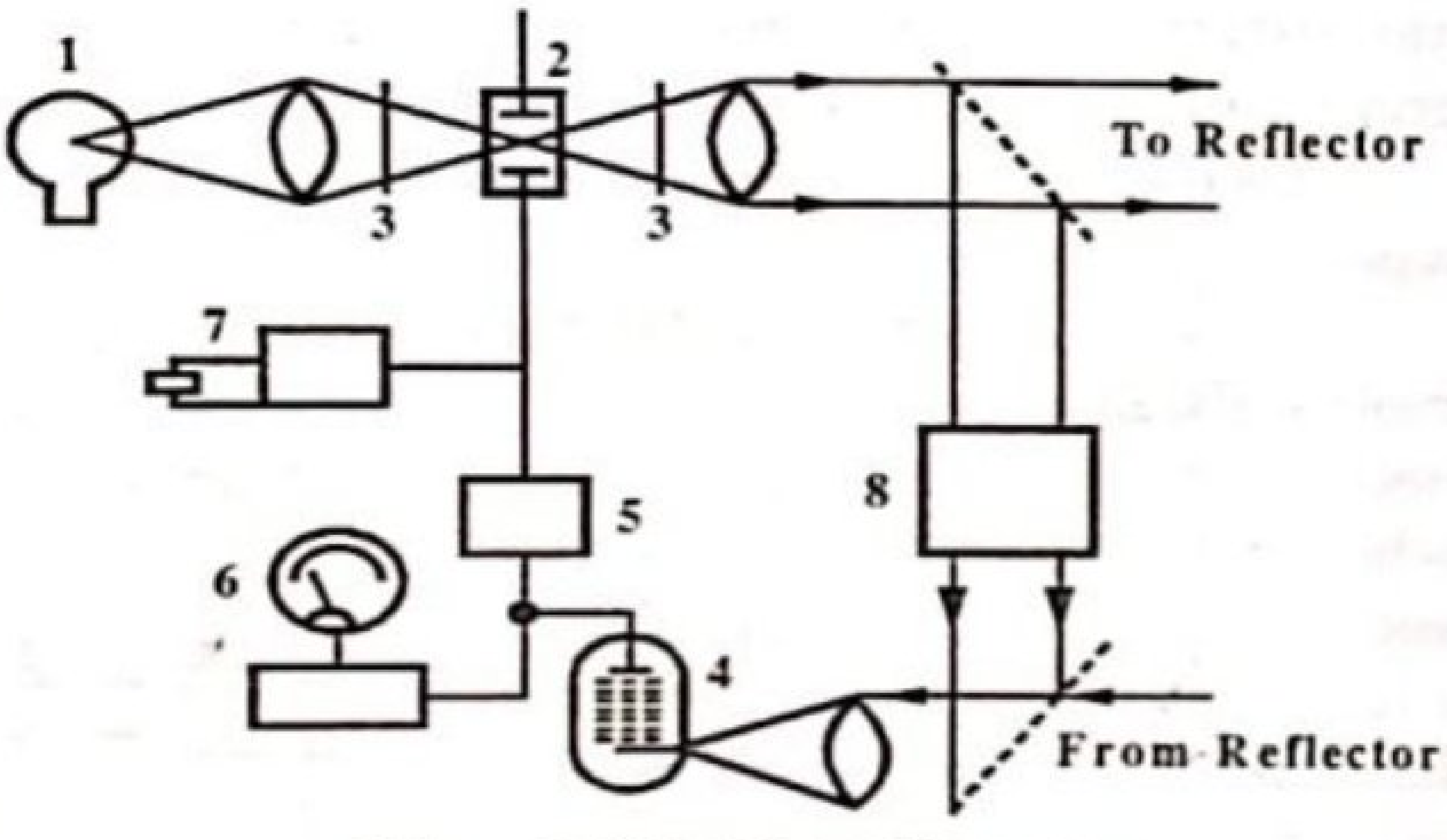


Fig. 2.89 Geodimeter

The geodimeter consists of following parts –

1. Incandescent lamp
2. Kerr cell
3. Photo tube
4. Nicol's prism
5. Variable electrical delay unit
6. Null indicator
7. Variable light delay unit
8. Crystal controlled oscillator.

(iii) Tellurometer – This instrument is based up on the principle of the propagation of radio waves. Thus in this instrument, high frequency radiowaves are used instead of light waves. This instrument is light in weight and portable. It can be used in day time as well as in lights. In this method atleast two instrument are required. In this method, line to be measured in both the directions. Microphones and head phones are required for two-way speech communication between the operators situated at each end of the line.

Out of two instruments, one is called as master set and other is called as remote set.

In this instrument, electromagnetic pulses transmitted by the instrument from station A are reflected at station B and returned to the initial point A. Thus the distance is measured twice, one way and back.

Let, D = Distance between A and B
t = Propagation time one way and back
R = Rate of wave propagation
Then, D = Rt/2

Thus, for determine the distance AB, it is necessary to measure T and to know the velocity of wave propagation R. The velocity of electromagnetic waves propagating in vacuum is about 299792.5 km/s.

(iv) Distomat – This is the trade name of EDM manufactured by LEICA (formerly known as WILD) company of Switzerland.

This instrument can measure distances from 20 m to 10 km, using a 3 cm carrier waves of different frequencies for fine measurements and coarse measurements. The following is the description of a typical Distomat Wild. D. I. Series.

The instrument uses infra-red beam with amplitude modulation to a frequency of about 15 MHz, which allows measurements to be made during day and night. The optical system consists of an attachment which can be fixed on the top of the telescope of a wild T-2 theodolite.

The control unit placed near the theodolite automatically maintains frequencies returned from the reflector at the other station. It provides a digital read out within few seconds with an accuracy of ± 20 mm upto a distance of 1 km. Both angular and distance meausrements can be made simultaneously. Before starting the operations, the temporary adjustments of the theodolite i.e. centering, levelling, focussing etc. are carried out. The position of the telescope and the distomat is adjusted so as to bisect the target at the other station through the telescope.

(v) Electronic Theodolite – It is differ in details from the older vernier models, but in general principle they are much the same. They are light and compact. They are provided with distomat attachment these become an automatic total survey system. At the touch of a single key the angles and distances are measured and recorded directly in a solid state memory device. In this theodolite, the date once collected can be processed by a computer.

It has arrangements to automatically resolve angular values and display them in a digital form. Display is achieved with the help of light emitting diodes (LEDS) or liquid crystal diodes (LCDS).

(vi) Electronic Planimeter – It is an instrument which plots the apexes of polygonal figures without the need to trace straight lines. Also it is able to make measurements of curved contours and very small areas. Hence the functions of it are not only as a planimeter and curvimeter, but as a measuring system. It consist of following parts –

(a) Control Panel – It offer a large number of facilities for the calculations of area and length.

(b) Display Screen – Number up to eight figures, decimals and negative number can be displayed on the display screen.

(c) High Friction Roller – A diamond wheel is used for greater precision and durability.

(d) Trace Arm – It travels upwards and downwards, on the surface to be measured.

(e) Trace Lens – It is large size eccentric lens having a wider field of view.

(f) Trace Point – This is the point to put on the top of the line to be traced.

(g) LED Indicator – It shows continuous mode tracing, when on.

(h) Start Switch – It is used to start the operation. In the point mode, it is used for plotting apexes by depressing it.

Q.79. Write down the different methods of measuring directions.

Ans. There are generally two methods of measuring directions –

(i) Chain angle method

(ii) Included angle method.

(i) Chain Angle Method – In this method, suitable points are selected on two lines of the traverse at the same distance from a point suppose that point is "A" and points "B" and "C" are selected on the traverse.

Since by referring fig. 2.90, $\sin \alpha/2 = P_1Q/AQ$

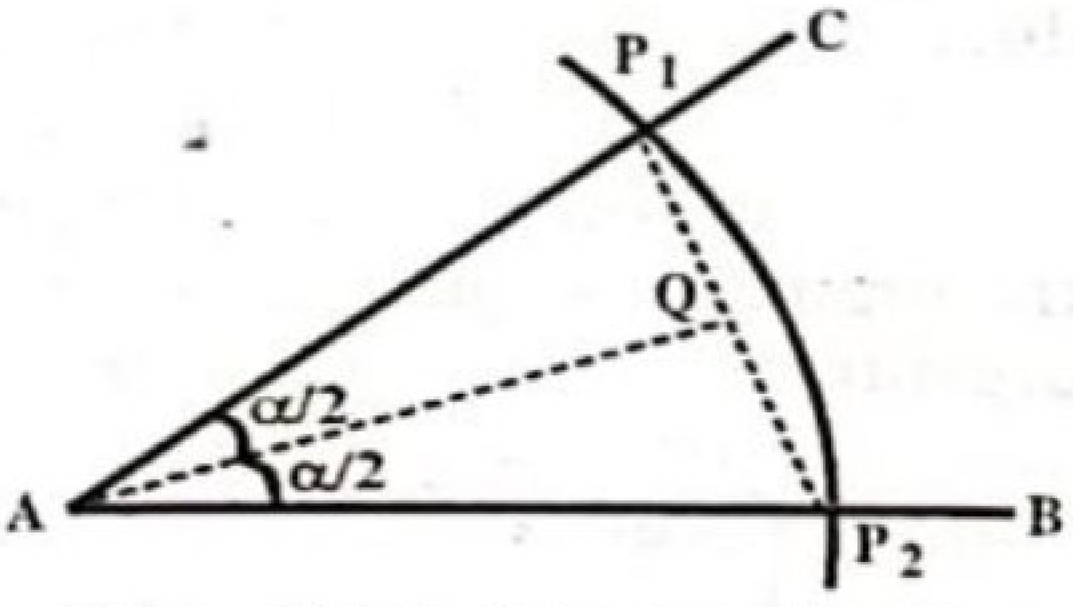


Fig. 2.90 Chain Angle Method

(ii) Included Angle Method – Included angles are measured by suitable instrument such as compass. These angles are measured with reference to the north direction as in case of the compass.

Q.80. Explain the term reciprocal levelling.

Ans. Refer Q.45.

Q.81. Explain the following terms –

Profile levelling, Check lines, Tie line, GTS benchmark, Well conditioned triangle, Local attraction error. ***(R.G.P.V., Dec. 2011)***

Ans. (i) Profile Levelling – Refer Q.44 (iv).

(ii) Check Lines – Refer Q.15 (iv).

(iii) Tie Lines – Refer Q.15 (iii).

(iv) GTS Benchmark – Refer Q.50 (i).

(v) Well Conditioned Triangle – The triangles which are very nearly equilateral are known as well conditioned triangles. A well conditioned triangle should not contain no angle greater than 120° and less than 30°.

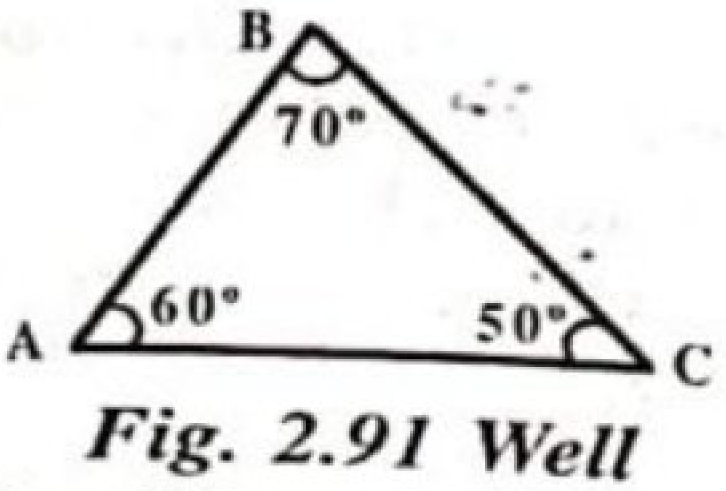


Fig. 2.91 Well Conditioned Triangle

(vi) Local Attraction – Refer Q.38.

UNIT
3
MAPPING AND SENSING

MAPPING DETAILS AND CONTOURING

Q.1. What do you mean by contours ? Describe about the characteristics of the contours. ***(R.G.P.V., Dec. 2006, April 2009, Dec. 2011)***

Or

Define contour. What are the various characteristics of contour ? ***(R.G.P.V., Dec. 2012)***

Or

Define contour. ***(R.G.P.V., March/April 2010)***

Or

What do you understand by the term contour ? Also show the properties of contours. ***(R.G.P.V., Dec. 2017)***

Ans. The nature of ground surface can be shown on plan by drawing the lines which represent the elevations of various points on the ground. A line joining the points of same elevation (R.L.) is known as a ***contour line***. A contour line, thus, intersects the ground surface at the points of same elevation. A map or plan representing a three-dimensional picture of the ground with the help of contour lines is called ***contour map*** or plan.

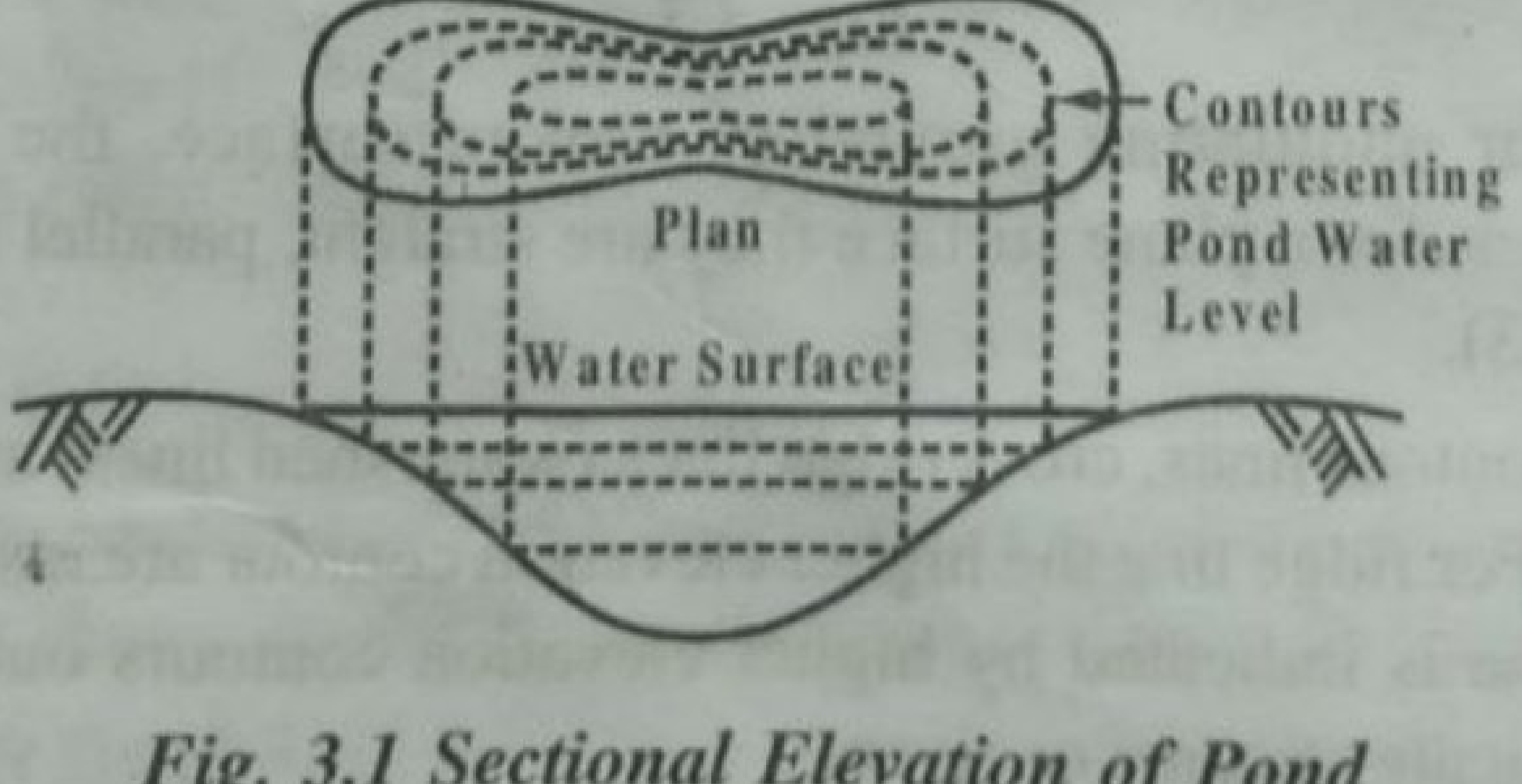


Fig. 3.1 Sectional Elevation of Pond

In nature, if we observe the surface of a still lake or pond, it has the same plane of elevation. Therefore, the points where the still surface touches the ground surface represents same elevation. If these points are now joined by a line, one gets a contour of water surface.

If the water level is increased or decreased, contour lines of different elevations will be obtained as shown in fig. 3.1.

The contour lines are characterised by following properties –

(i) All points on a contour line have the same elevation.

(ii) Two contour lines never intersect each other because each contour line represent own elevation. But, in case of overhanging cliff, the contour lines cross each other. (Refer fig. 3.2).

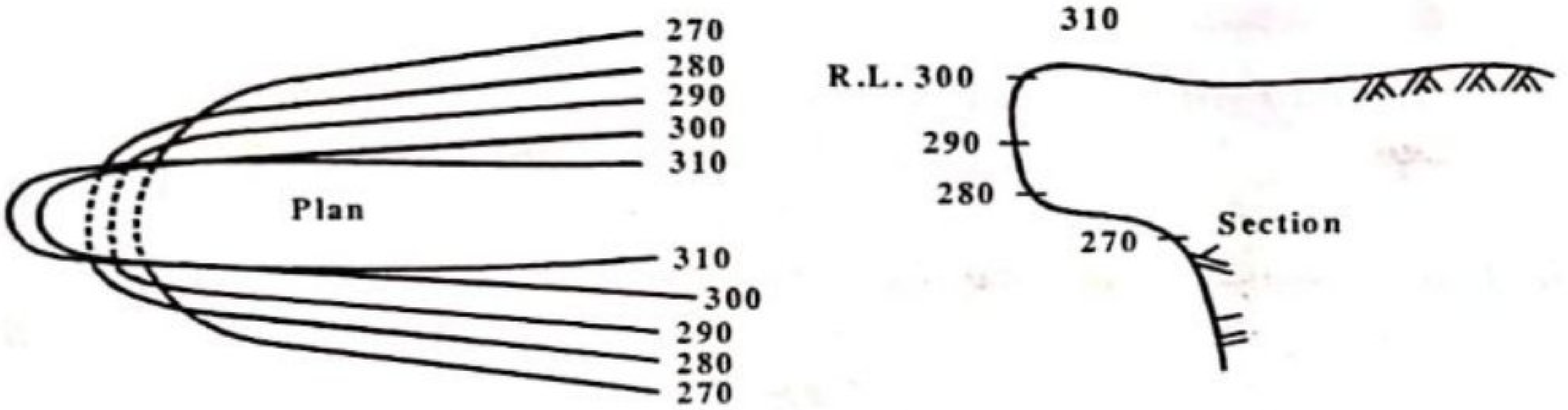


Fig. 3.2 Overhanging Cliff

(iii) Spacing between contour lines indicate the nature of ground (Fig. 3.3).

(a) Closely spaced – steep slope (b) Wide apart – gentle or flat slope

(c) Equally spaced – uniform slope

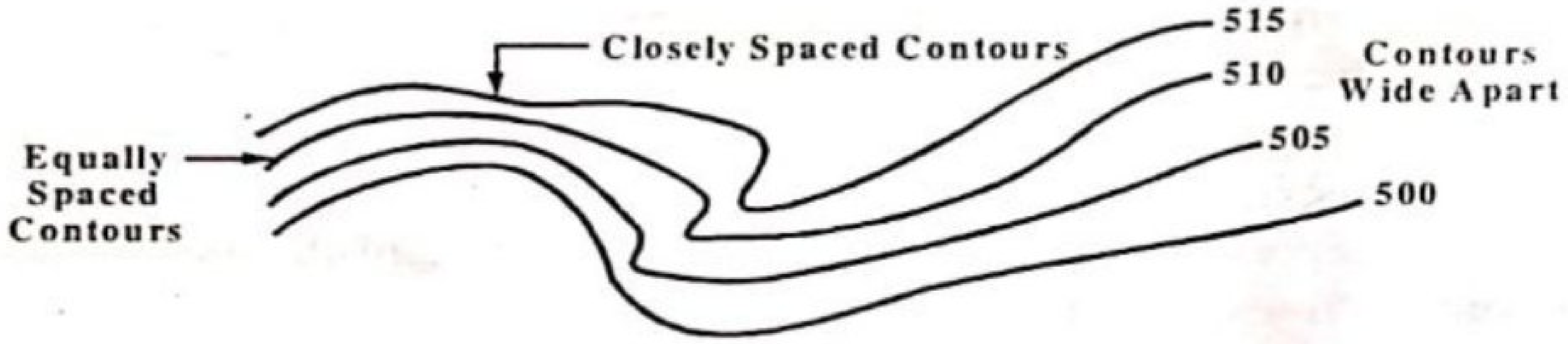


Fig. 3.3

(iv) For undulating ground or broken surface, the contours are rregular, whereas for a plane surface they are straight, parallel and uniformly spaced (Fig. 3.3).

(v) Contour lines, cross ridge lines (watershed lines) and valley lines at right angles. For ridge line the higher elevation contour are inside the loop or end. Valley line is indicated by higher elevation contours outside the loop. Valley lines indicate streams or rivers.

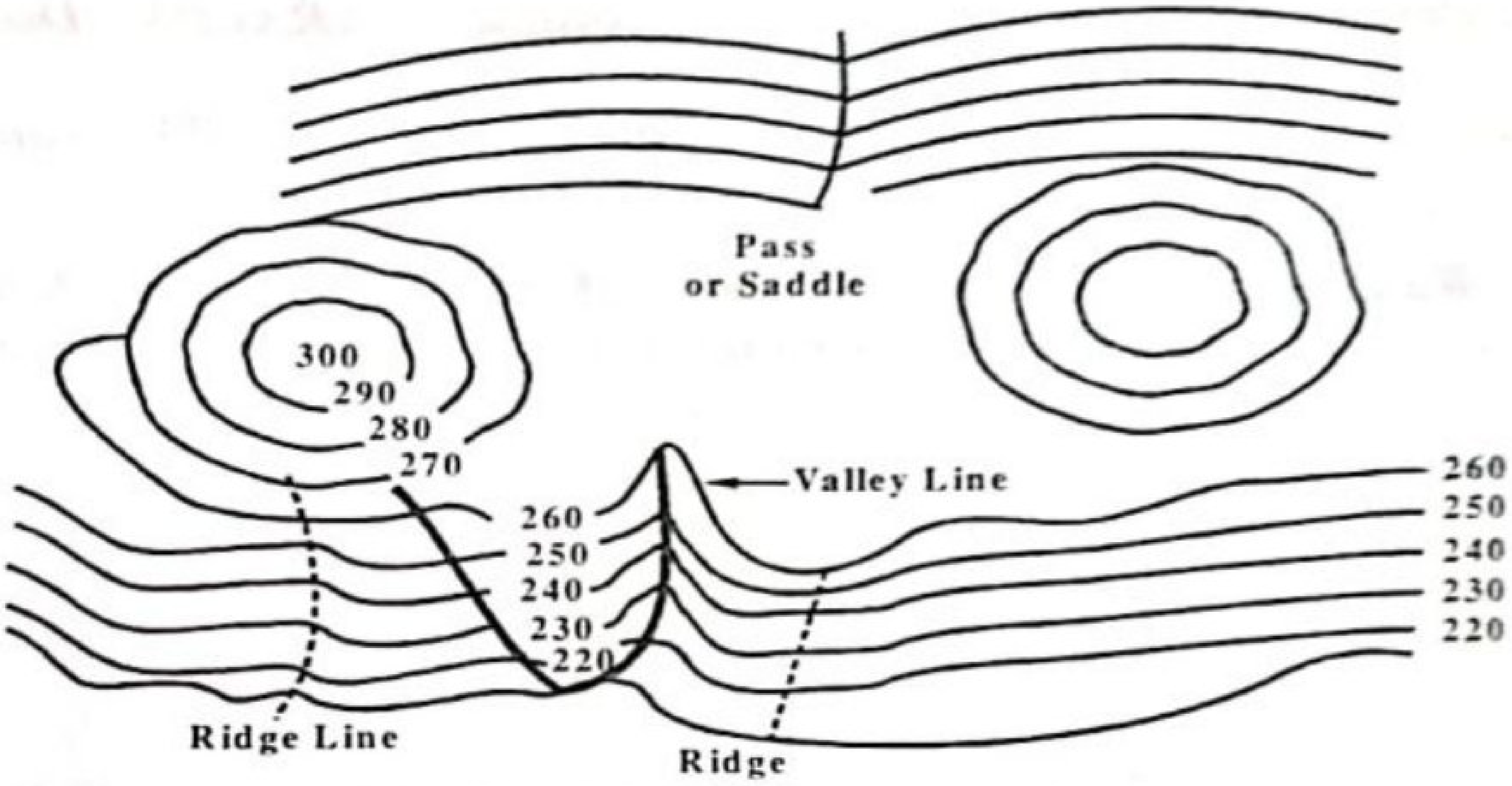


Fig. 3.4 Ridge and Valley Lines

(vi) A series of closed contour lines with higher elevations inside the loop indicate a hill. If in such a closed loop, lower values of contours are inside, it indicates a depression or pond, as shown in fig. 3.5.

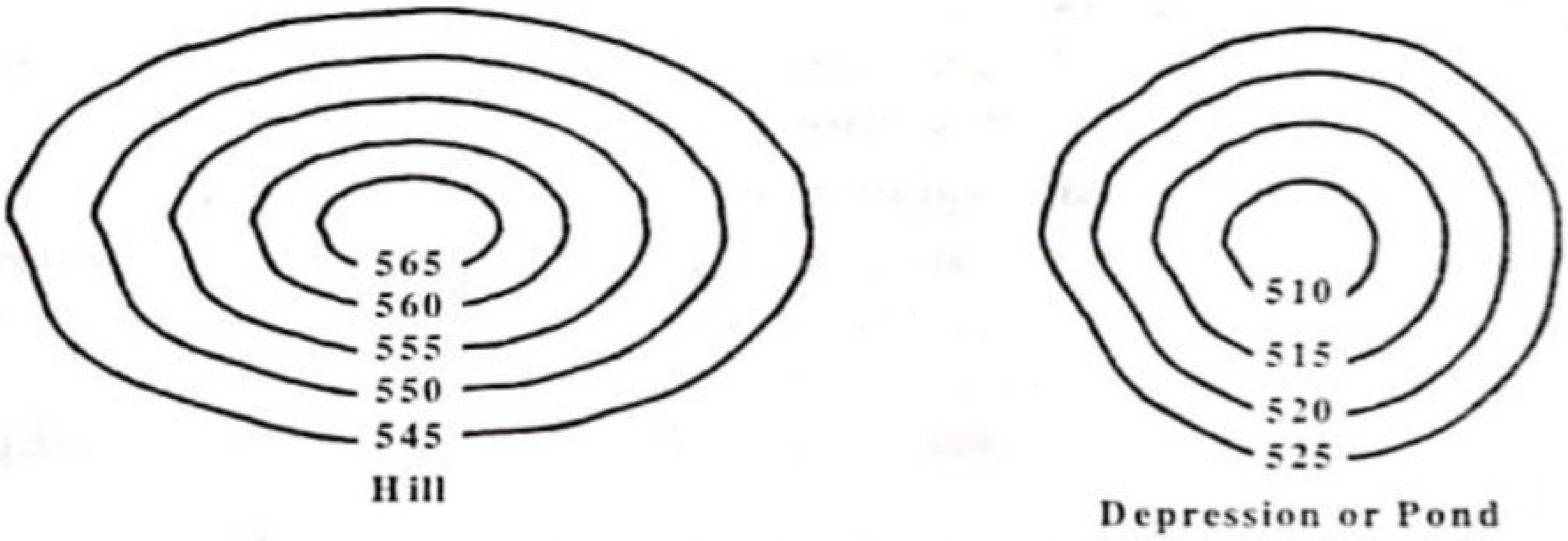


Fig. 3.5

(vii) A contour line always closes on either inside the boundary of maps or outside it.

Q.2. Show with neat sketches the characteristic features of contour lines for the following –

(i) A ridge (ii) A vertical cliff.

(R.G.P.V., June 2015)

Ans. Refer Q.1.

Q.3. Draw contours of ridge and a valley line assigning suitable values to the contour shown in the figure (in your answer).(R.G.P.V., June 2014)

Ans. Refer fig. 3.4, Q.1.

Q.4. Briefly discuss the properties of contour. ***(R.G.P.V., Dec. 2015)***

Or

Enumerate various properties of contour. ***(R.G.P.V., June 2016)***

Ans. Refer Q.1.

②

Q.5. Explain the term contour interval. Discuss the consideration in making a choice of proper contour interval. ***(R.G.P.V., June 2011)***

Ans. Contour interval is the difference in elevation between two consecutive contour lines. For a contour map, the contour interval is always constant.

Before preparing a contour map, the contour interval required is decided by considering the following factors on which the contour interval depends.

(i) Nature of the Ground Surface – If the ground surface is even or flatter, the contour interval will be smaller. In case the ground is very much undulating or slopping, the contour interval adopted will be larger, otherwise the contour lines will be very close to each other.

(ii) Scale of the Map – If the scale of the map is small, the contour interval is large. This because the smaller values of elevations will not be reflected on the map and as such obtaining these values, field work and time are wasted. To avoid this, larger contour interval is adopted for small scale maps. For large scale maps the contour interval is small.

(iii) The contour interval depends on the purpose and extent of survey.

(iv) Contour interval also depends on ***time and expenses required*** for survey. If the time available for survey is sufficient, as also the finance, then small contour interval may be selected.

The following contour intervals may be adopted for various purposes of contour maps –

(a) Small scale maps of rough country : 5 m to 25 m.
(b) Large scale maps of flat country : 0.5 m.
(c) Location survey : 2 to 3 m.
(d) Building sites : 0.3 to 0.5 m.
(e) Reservoirs and town planning works : 0.5 to 1 m.
(f) Detailed design of works : 0.5 m.

Q.6. Explain the factors on which contour interval depends. ***(R.G.P.V., June 2014)***

Ans. The factors on which contour interval depends are as follows –

(i) Time and Expanse of Field and Office Work – When the contour interval is small, the time and expenditure to conduct the survey is more.

(ii) Purpose and Extent of Survey – The contour interval largely depends upon the purpose and extent of survey. For example, when a contour plan is required for the calculation of earthwork or for the design of an engineering structure, the area involved will be small and as the detailed information regarding the topography of the country is needed, the contour interval may be small. But in the case of location and preliminary surveys for reservoirs, drainage lines, line of communication etc., the area involved is very large and as very detailed information of the country is not essential, the contour interval is comparatively large.

(iii) Nature of Country – In uniformly sloping and flat country, the contour interval may be large. But in the case of undulating ground, the contour interval should essentially small so that the contour plan clearly shows the character of the country.

(iv) Scale of Plan – The contour interval should be in inverse ratio to the scale of the map or plan.

Q.7. Define the following terms related to contour –

(i) Contour
(ii) Horizontal equivalent
(iii) Cliff
(iv) Contour interval
(v) Grade contour
(iv) Ghat tracer.

(R.G.P.V., June 2013)

Ans. (i) Contour – Refer Q.1

(ii) Horizontal Equivalent – It is the horizontal distance between two consecutive contour lines. The horizontal equivalent depends on the slope of ground. For a steeper slope, horizontal equivalent will be less as the contour lines are spaced close to each other.

(iii) Cliff – Refer Q.1.

(iv) Contour Interval – Refer Q.5.

② ***(v) Grade Contour*** – A line lying on the ground which maintains a constant inclination to the horizontal is known as ***contour gradient***. It is find out by instrument called, clinometer.

(vi) Ghat Tracer – The ghat tracer is a simple instrument which is used for measuring the slopes. Specially it is useful for setting out a grade contour on a given gradient in the preliminary survey of a road in a hilly area.

Q.8. What is contour and contour interval ? ***(R.G.P.V., Dec. 2015)***

Ans. Refer Q.1 and Q.5.

Q.9. Write short note on contour interval. ***(R.G.P.V., Dec. 2016)***

Ans. Refer Q.5.

Q.10. Define the term horizontal equivalent. ***(R.G.P.V., June 2015)***

Ans. Refer Q.7 (ii).

Q.11. Define contour map. State the uses of contour maps.

Ans. **Contour Map** – It is the map of the ground surface which gives the elevation of different points of the ground surface.

Uses – Following are the uses of contour maps –

(i) Suitable site can be selected for construction activities.

(ii) Reservoir capacity can be determined.

(iii) Alignment for roads, canals, transmission lines are done efficiently with the help of contour maps.

(iv) Nature of the ground surface may be determined.

(v) Estimating the quantities of earth work.

(vi) The nature of ground, i.e. flat, uniformly slopping, undulating or hilly, etc., can be known.

(vii) It is possible to select the most suitable and economical site for works such as location of roads, railways, canals, pipelines, dams, reservoirs, etc. by using contour map.

(viii)Intervisibility between two stations can be determined by using contour map.

(ix) Estimation of volume of reservoir storage water, volume of earth work in cutting and embankment can be done by using contour map.

(x) A line of given gradient can be traced on contour map.

(xi) Military operations can be planned with the help ofcontour maps.

(xii) These are used for obtaining data used in design and construction of irrigation structures such as dams.

Q.12. Explain step by step procedure, how the capacity of reservoir can be determined using contour maps. ***(R.G.P.V., June 2012)***

Or

Explain how contour maps can be used to draw cross-sectioning and to find out capacity of a reservoir. ***(R.G.P.V., June 2014)***

Ans. The capacity of a reservoir can be determined from the contour plan. This is a particular case of computation of volume from the contour plan when the finished surface is a level surface.

Fig. 3.6 shows the contour plan of the reservoir on the upstream of a dam. The contour of 150 m represents the water edge at full reservoir level

(F.R.L.) of 150.00. The water spread at R.L. of 150.00 is equal to the surface area of the reservoir when it is full. Likewise, the water spread at R.L. of 140, 130, 120, 110 and 100 are also shown.

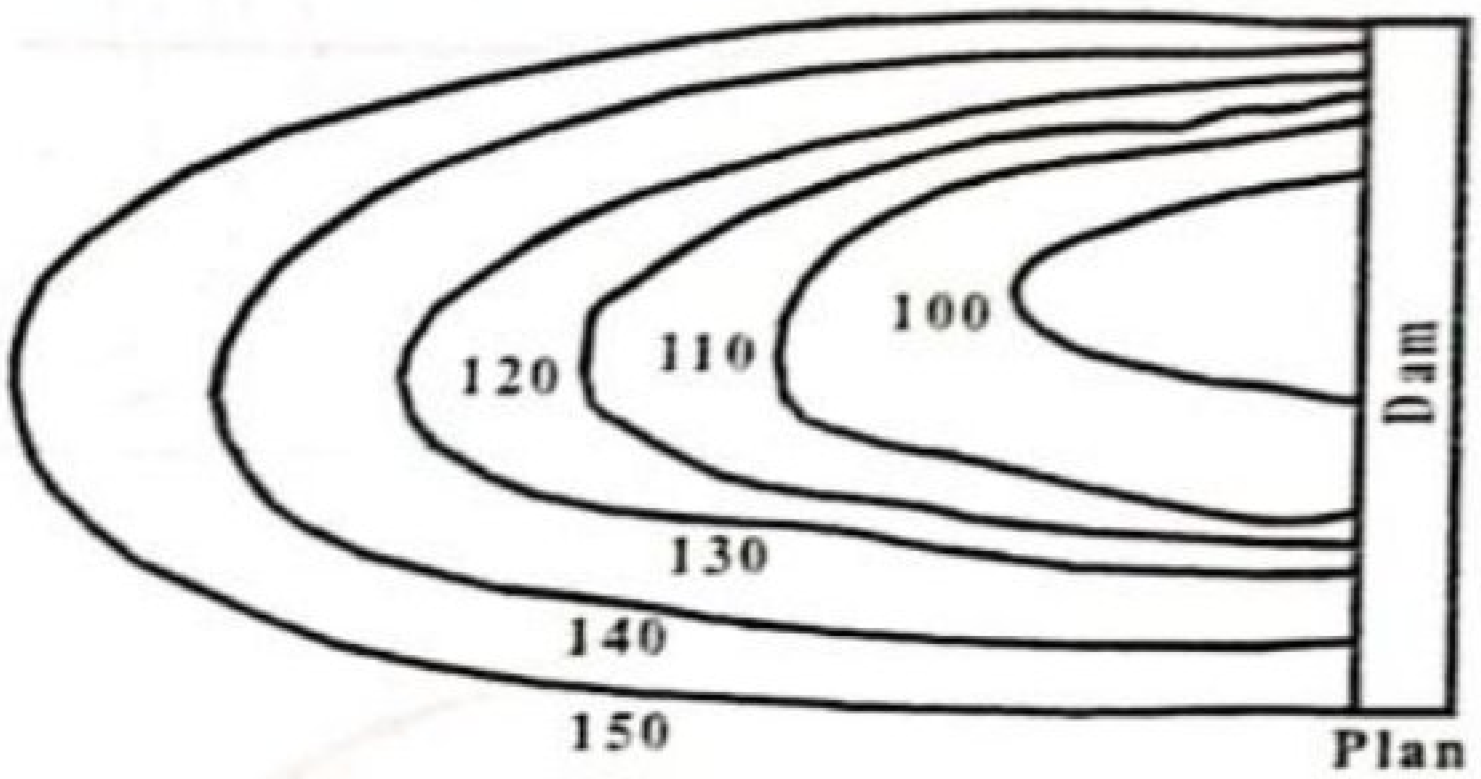


Fig. 3.6

The volume is computed by assuming that the reservoir is divided into a number of horizontal slices. For computation of the volume, the whole area lying within a contour line and the upstream of the dam is determined with a planimeter. It must be noted that the areas required are the whole areas upto the dam and not the areas between adjacent contours.

The whole areas enclosed by successive contour lines are taken as horizontal sections and the vertical interval between them as the constant distance for computation of the volume by the trapezoidal rule or the prismoidal formula.

Let $A_1, A_2, A_3, \ldots$ be the whole areas included by the contours of 150, 140, 130, 120, etc. and let h be the contour interval.

The volume of the reservoir can be obtained from the trapezoidal rule as

$$V = h\left[\frac{A_1 + A_n}{2} + A_2 + A_3 + \ldots + A_{n-1}\right]$$

Alternatively, by the prismoidal formula

$$V = \frac{h}{3}[A_1 + A_n + 4(A_2 + A_4 + \ldots) + 2(A_3 + A_5 + \ldots)]$$

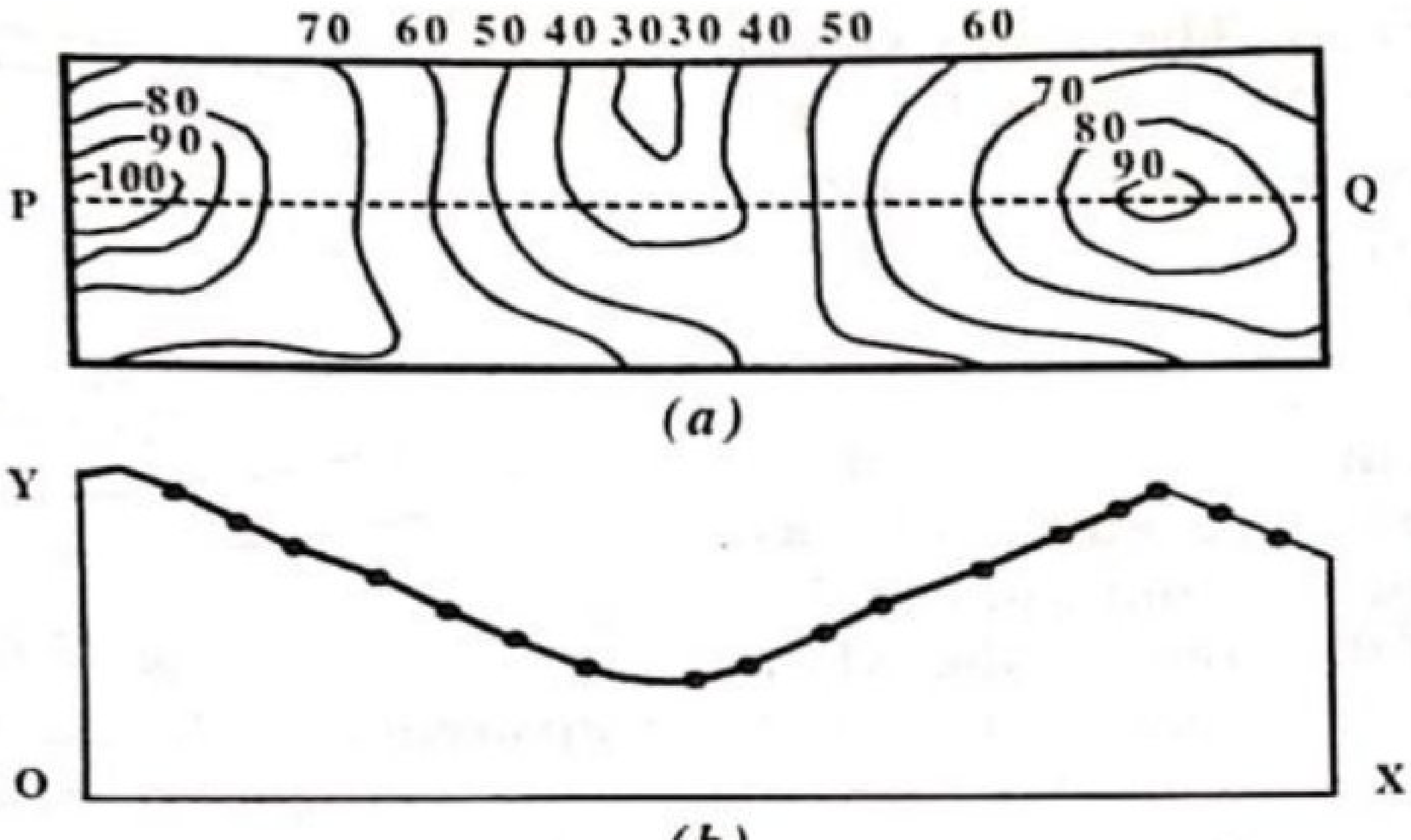
Of course, the prismoidal formula is applicable only when n is an odd number.

Q.13. Explain in details how the contour map can be used for engineering purposes. ***(R.G.P.V., June 2012)***

Ans. The different uses of contour map for engineering purposes are as follows –

(i) Drawing of Sections – On a contour map sections in any direction may be drawn to study the general shape of the ground. Such sections are also required to calculate the earth work needed for road, railway or canal projects [fig. 3.7 (a)].

Let it be required to draw the section along the line PQ. The points at which the various contours intersect this line are plotted on the axis OX and their corresponding heights are plotted along axis OY to any convenient scale. The ends of the perpendiculars representing the contour heights may then be joined by smooth straight lines to give the configuration of ground surface [fig. 3.7 (b)].



(a)

(b)

Fig. 3.7 A Cross-section Along PQ

(ii) Section of the Alignment of Canals – Refer fig. 3.8.

Suppose a reservoir is constructed at R across a river and an irrigation canal RL is required to be constructed to irrigate areas of villages Rampur and Shyampur located on opposite slopes of the ridge.

We know that water in canals flows under gravity. From the contour map it may be noted that the elevation of the reservoir site R is 547 m approximately. The canal alignment should therefore be kept below this level. The water shed or ridge line is first marked by a dotted line. From R, the canal is taken along RS where S is a point on the water shed line and its height is approximately 542 m. Points may be chosen by considering the other factors to avoid the construction of aqueducts over the intercepting drainage enroute. From S onward the canal may be aligned along the water shed line S.T.P.L. Branch canals may then be constructed on either slopes so that the areas of both villages may be irrigated.

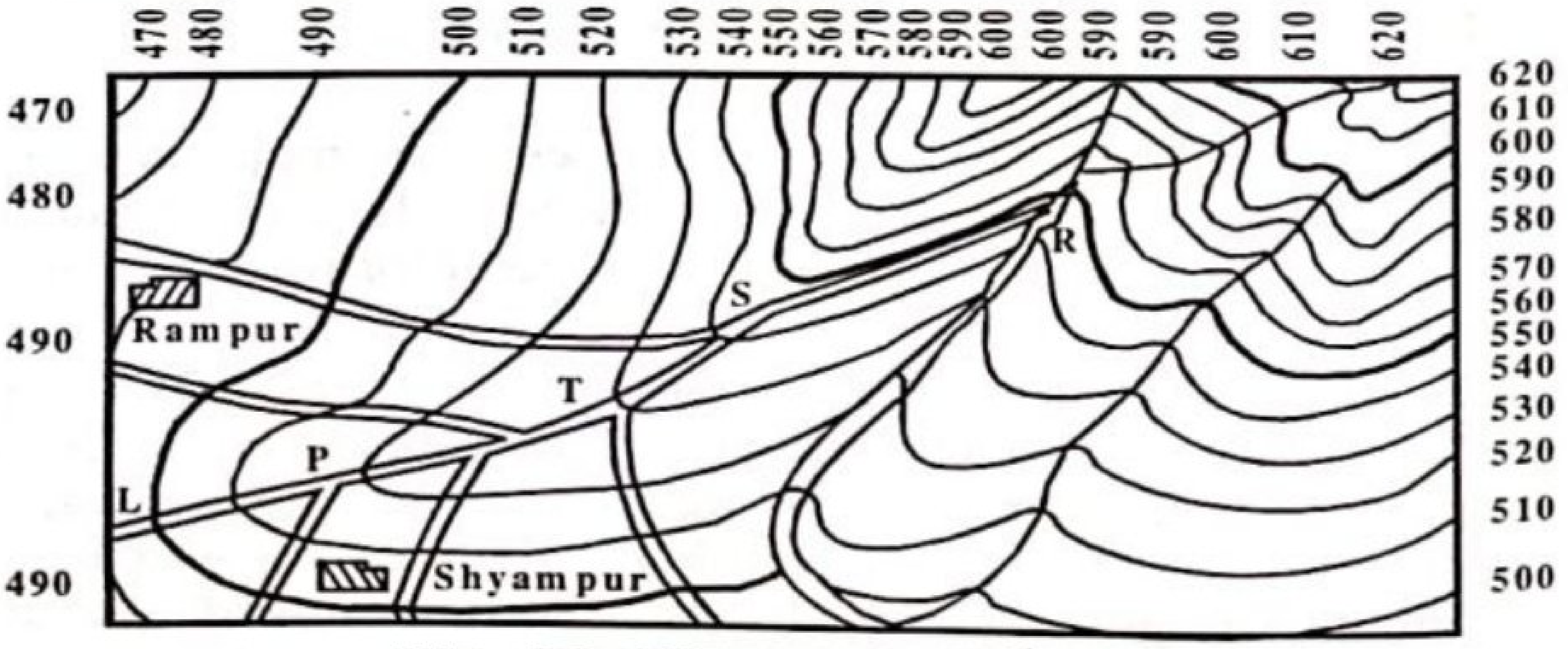


Fig. 3.8 Alignment of Canals

It may be noted that in the absence of a contour map, the layout of the canals cannot be decided economically.

(iii) Tracing of Contour Gradients and Location of Routes – On a contour map, the alignment of a proposed road or railways may be decided and located by drawing contour gradients as follows –

Let the contour interval on the contour map supplied is 10 metres and an upward gradient of 1 in 30 is required to be drawn from the point A to the point B.

Horizontal equivalent = 10 × 30 = 300 m

With A as centre and a radius representing 300 metres on the scale of the map, draw an arc to cut the 60 m contour at 'a'. Similarly with 'a' as centre and with the same radius draw another arc to cut 70 m contour at b. In a similar manner points c and d are obtained. When an arc with d as centre is drawn it cuts 100 m contour at e end e'. Point e' though in the continuance of the route, is rejected as when, d and e' are joined it cuts 100 m contour again and thus a deep cutting is involved. At e, the arc of the same radius if drawn cuts 110 m contour nowhere. To overcome this difficulty, the 105 m contour is interpolated and half the radius is used to obtain the point f. Location of a number of points is made till the last point is reached.

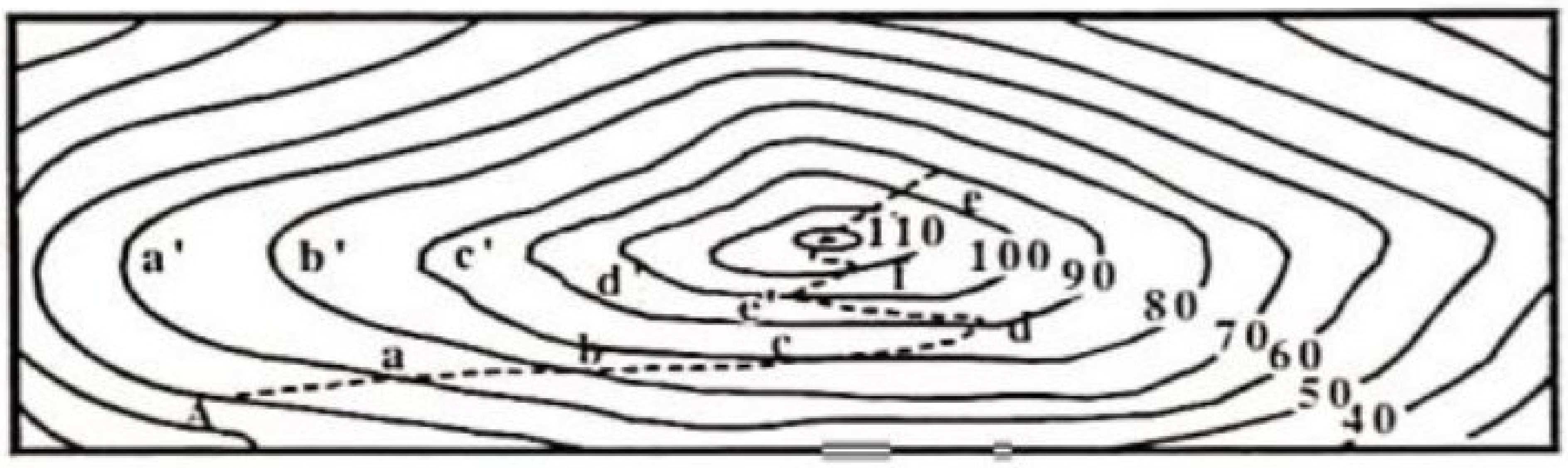


Fig. 3.9 Tracing a Contour Gradient

During the process of drawing arcs it may be noted that it cuts next higher contour at two points. Only the point suitable for the alignment is accepted and the other is ignored.

During construction the route of the road is made to follow the gradient line so obtained as closely as possible.

(iv) Measurement of Catchment Area – The area of the tract of land which contributes water which flows over the surface of the earth into stream at any point is called catchment area. The limit of such an area can be marked sufficiently accurate on a contour map. The line that marks the limits of drainage area possesses the following characteristics –

(a) The line follows the highest ridge line and divides the drainage area from other area.

(b) It follows the ridges.

(c) It is everywhere perpendicular to the direction of the contours. An imaginary line possessing the above characteristics is generally known as watershed-line.

A line is drawn on the map with dash and dots to mark the bounding limits of the catchment area. The area is then computed with the help of a planimeter.

Knowing the maximum water level of a reservoir, the extent of the area to be submerged will be the area enclosed by the contour of the maximum water level and its area may also be calculated by a planimeter. The trac of area to be submerged under water = $\frac{a}{A} \times 100\%$ where 'a' is the area of water body of the reservoir and A is the area of its catchment basin.

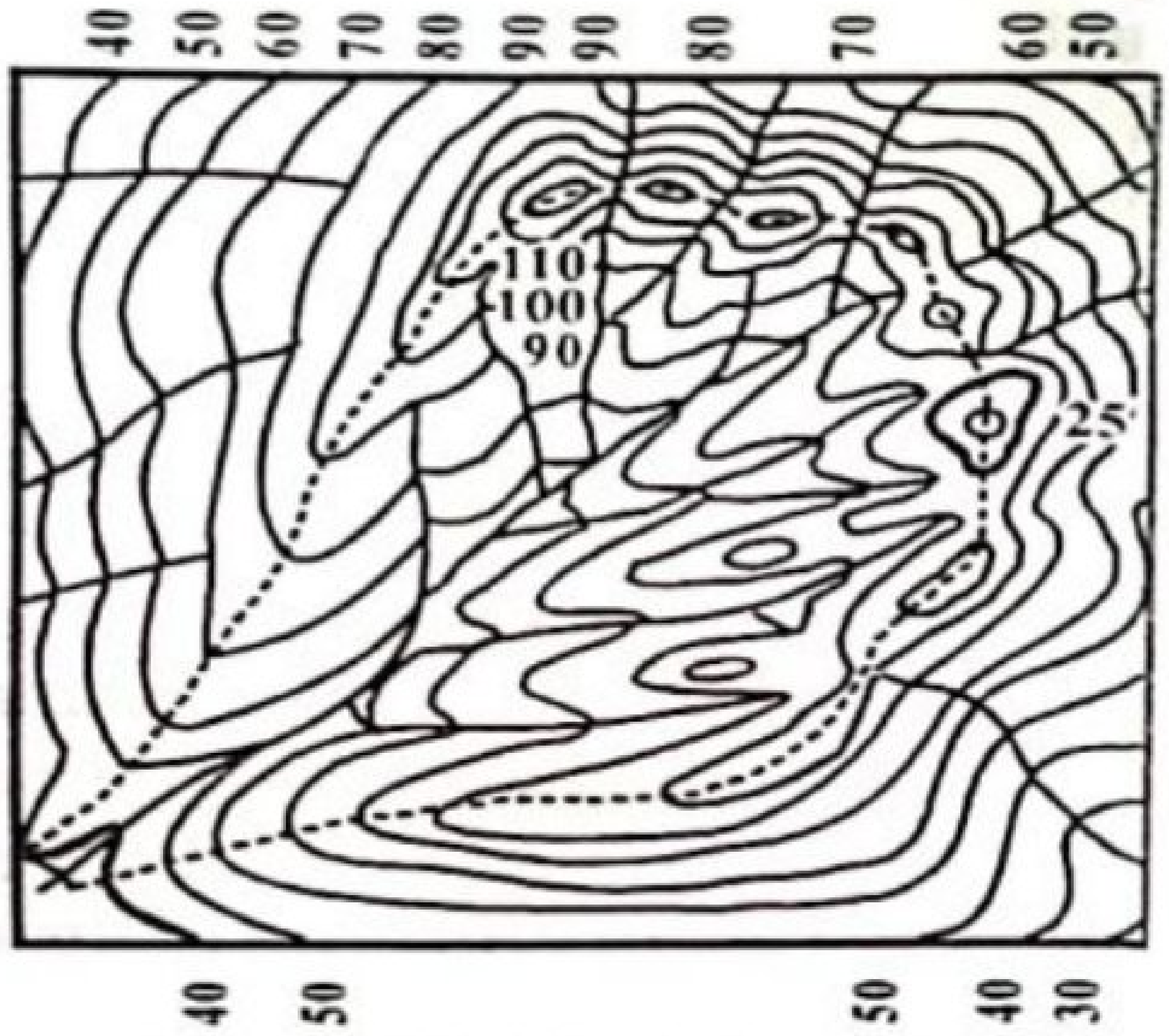


Fig. 3.10 A Catchment Area

(v) ***Calculation of Storage Capacity of Reservoirs*** – The capacity of a reservoir at dam site may be easily calculated with the help of a contour map. Knowing the maximum water level of the dam, and the contour interval, the area enclosed at respective elevations may be found out by a planimeter. The capacity of a reservoir may then the computed by using Trapezoidal or Prismoidal formula.

$$\text{Volume, } V = h\left[\frac{A_1 + A_n}{2} + A_2 + A_3 + \ldots.. + A_{n-1}\right] \quad \ldots(i)$$

Trapezoidal formula

$$V = \frac{h}{3}[A_1 + A_n + 4(A_2 + A_4 + \ldots..) + 2(A_3 + A_5 + \ldots..)] \quad \ldots(ii)$$

Prismoidal formula

where $A_1, A_2, A_3, \ldots.., A_n$ are the areas enclosed between successive contours and h is the contour interval.

Q.14. Describe uses of contour maps and methods of contouring.
(R.G.P.V., Nov./Dec. 2007)

Or

What are the various direct and indirect methods of contouring ? Explain any one indirect method of contouring. (R.G.P.V., June 2013)

Ans. **Uses of Contour Maps** – Refer Q.11.

Methods of Contouring – The location of contours means the process by which the points having the same elevation are obtained.

There are mainly two methods of locating contours –

(i) Direct method (ii) Indirect method.

(i) Direct Method – In this method, the contours are directly located on the ground and the points of given contour are marked on the ground. These points are thereafter surveyed and their positions in the horizontal plane are found out within the given boundary. Now, the contour can be plotted on the map. The field work involved in this method is as follows –

After setting and levelling the dumpy level –

(a) Take backsight on the Bench Mark.

(b) Determine the height of instrument (reduced level of collimation plane). Height of instrument = R.L. of B.M. + Backsight.

(c) Calculate the staff reading required for a particular contour by the relation, Desired staff reading = Height of instrument – Contour elevation

(d) Direct the staffman to move within the boundaries of area so as to get the desired staff reading through the dumpy level.

(e) Mark the points on the ground by pegs or coloured tags.

(f) Repeat the procedure for other contours either with the same position or by shifting the instrument.

(g) Carry out a survey to determine relative positions of these points of a contour line in the field.

(h) Plot the survey to a suitable scale on the paper.

From the above discussion, it may be noted that direct method of contouring is suitable for small areas (like hilly areas) where high precision is required. However the method is tedious and time consuming.

(ii) Indirect Method – In this method levelling work is carried out in the field and location of contour points is done in the office. The field work involves –

(a) Establishing a definite pattern of ground points whose relative positions are known.

(b) Determining the elevations of these points in the field. The indirect method is cheaper, quicker and less tedious than direct method.

The various indirect methods of contouring are –

(a) Method of cross-sections

(b) Method of squares

(c) Tacheometric contouring.

(a) Method of Cross-sections – This method involves running a longitudinal line along the centre of the area under consideration. Cross-sections at definite intervals depending on the nature of ground are laid at right angles to the centre line and a grid is prepared. Along the centre line and on cross-sections at known intervals, the staff is held and readings are taken by dumpy level to determine the R.L.s. of points.

The centre line, cross-sections and R.L.s., of points are plotted on the plan and contours are interpolated through these points.

This method is most commonly adopted in route survey such as survey for roads, railways and canals etc.

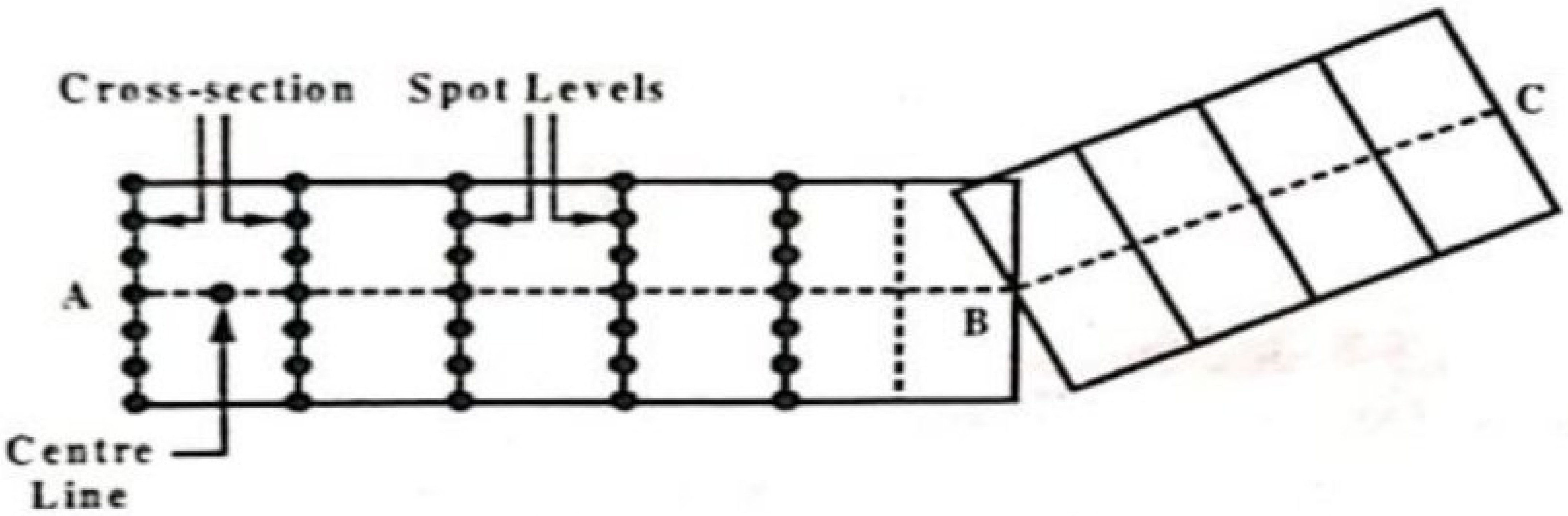


Fig. 3.11 AB and BC are the Centre Lines of Alignment

(b) Method of Squares – In case of small area, the whole area is divided into squares of sizes 5 m × 5 m to 20 m × 20 m depending on the nature of ground, and the corners of squares are marked with pegs. Using dumpy level, the elevations of corners of squares are determined. At the intersection of diagonals of a square, the elevations are determined. These squares are plotted and R.Ls., of corners are written upto two decimal points. Then the contour lines are interpolated.

(c) Tacheometric Contouring – This method is most suitable for preparing a contour map of a hill where the slope is steep.

With the help of a tacheometer one can get elevation of a point as well as its horizontal distance from the instrument. Therefore in this method, radial lines at regular angular intervals are set out from the instrument and on each line the ground points are located by taking (1) three staff reading (top, bottom and axial), (2) vertical angle.

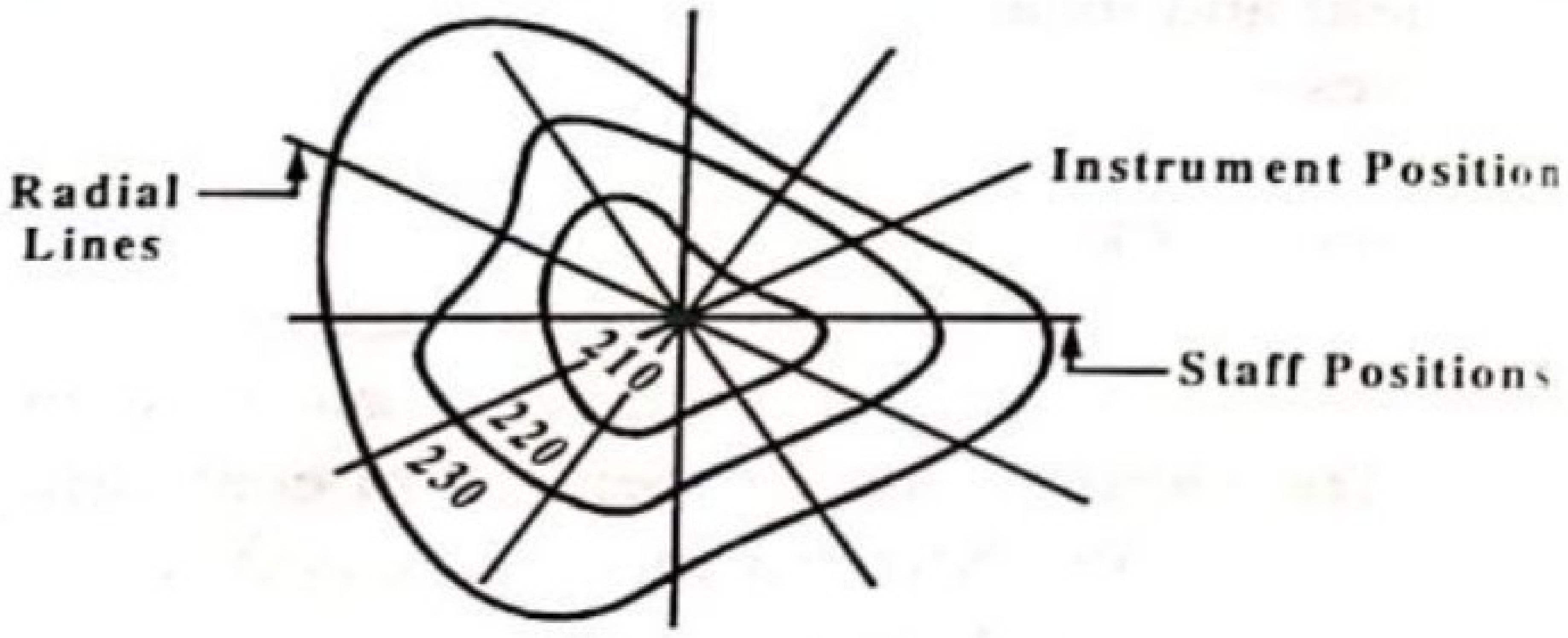


Fig. 3.12 Tacheometric Contouring

From these readings both horizontal and vertical distance of respective points are calculated and their elevations are determined.

The survey work is plotted and interpolation of contours is done.

Q.15. Explain the graphical method of interpolation of contour with example. ***(R.G.P.V., Dec. 2014)***

Ans. In the graphical method, interpolation is done with the help of a tracing cloth or a tracing paper. There are two methods.

First Method – The first method is shown in fig. 3.13. On a piece of tracing cloth, at an interval representing 0.2 metre, several lines are drawn parallel to each other. If needed, each fifth line may be made dark to show each metre interval. Let the bottom line of the figure, so prepared on the tracing cloth, show an elevation of 99 m and let it be needed to interpolate contours of 99.5 m, 100 m and 100.5 m value between two points A and B having elevations of 99.2 m and 100.7 m respectively. Keep the tracing cloth on the line in such a way that point A may lie on a parallel showing an elevation of 99.2 m. Now rotate the tracing cloth on drawing in such a way that point B may lie on a parallel showing 100.7 m. The points at which the parallels showing 99.5 (point x), 100.0 (point y) and 100.5 (point z) may now be pricked through the respective positions of the contour point on the line AB.

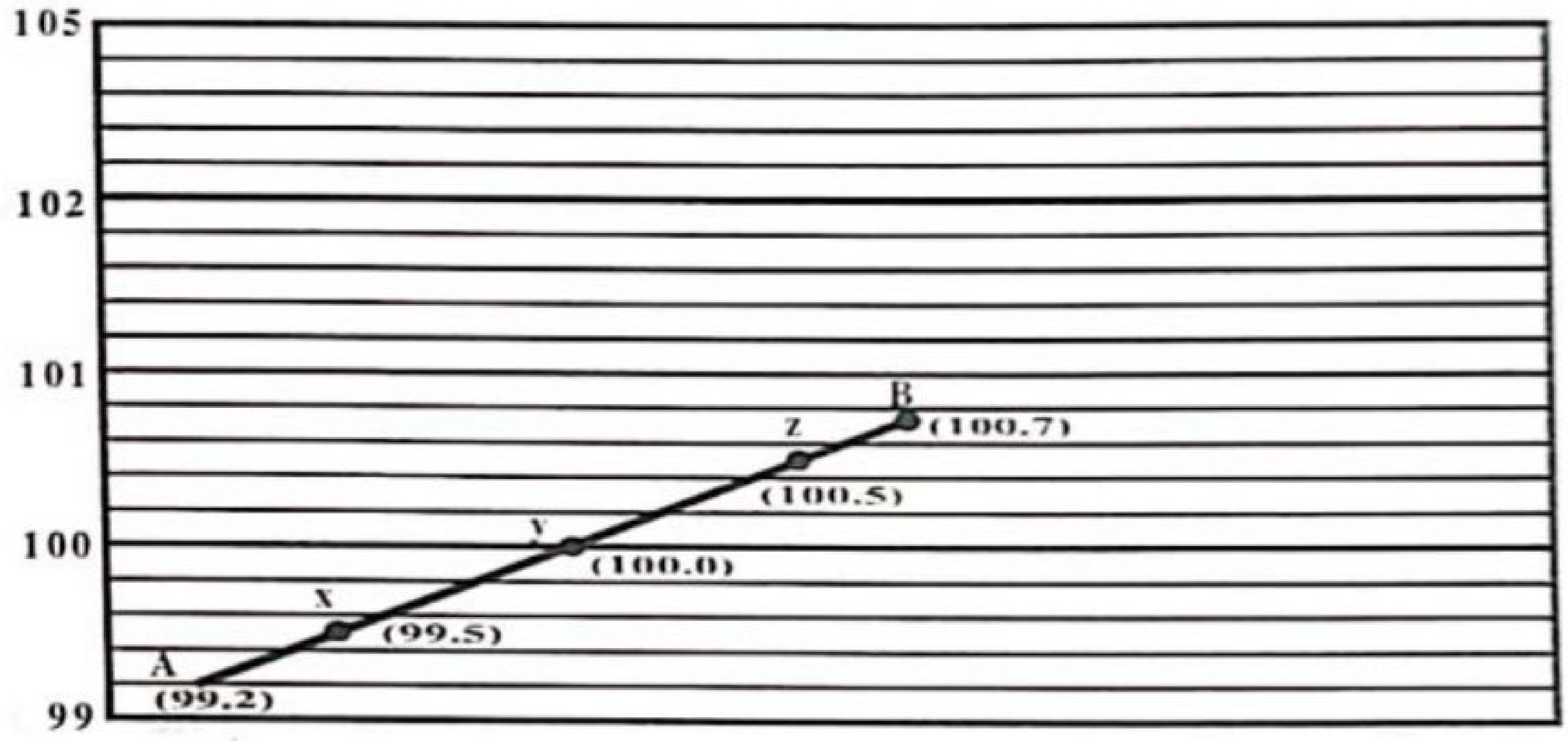


Fig. 3.13

Second Method – The second method is shown in fig. 3.14. A line XY of any convenient length is taken on a tracing cloth and divided into several parts, each showing any particular interval, say 0.2 m. On a line perpendicular to XY at its mid-point, a pole O is chosen and radial lines are drawn joining the pole O and the division on the line XY. Let the bottom radial line show an elevation of 97.0. If needed, each fifth radial line showing one metre interval may be drawn dark. Let it be need to interpolate contours of 98, 99, 100 and 101 m elevations between two points A and B having elevations of 97.6 and 101.8 m. Arrange the tracing cloth on the line AB in such a way that the point A and B lie simultaneously on radial lines showing 97.6 and 101.8 m respectively. The points at which radial lines of 98, 99, 100 and 101m intersect AB may then be pricked through.

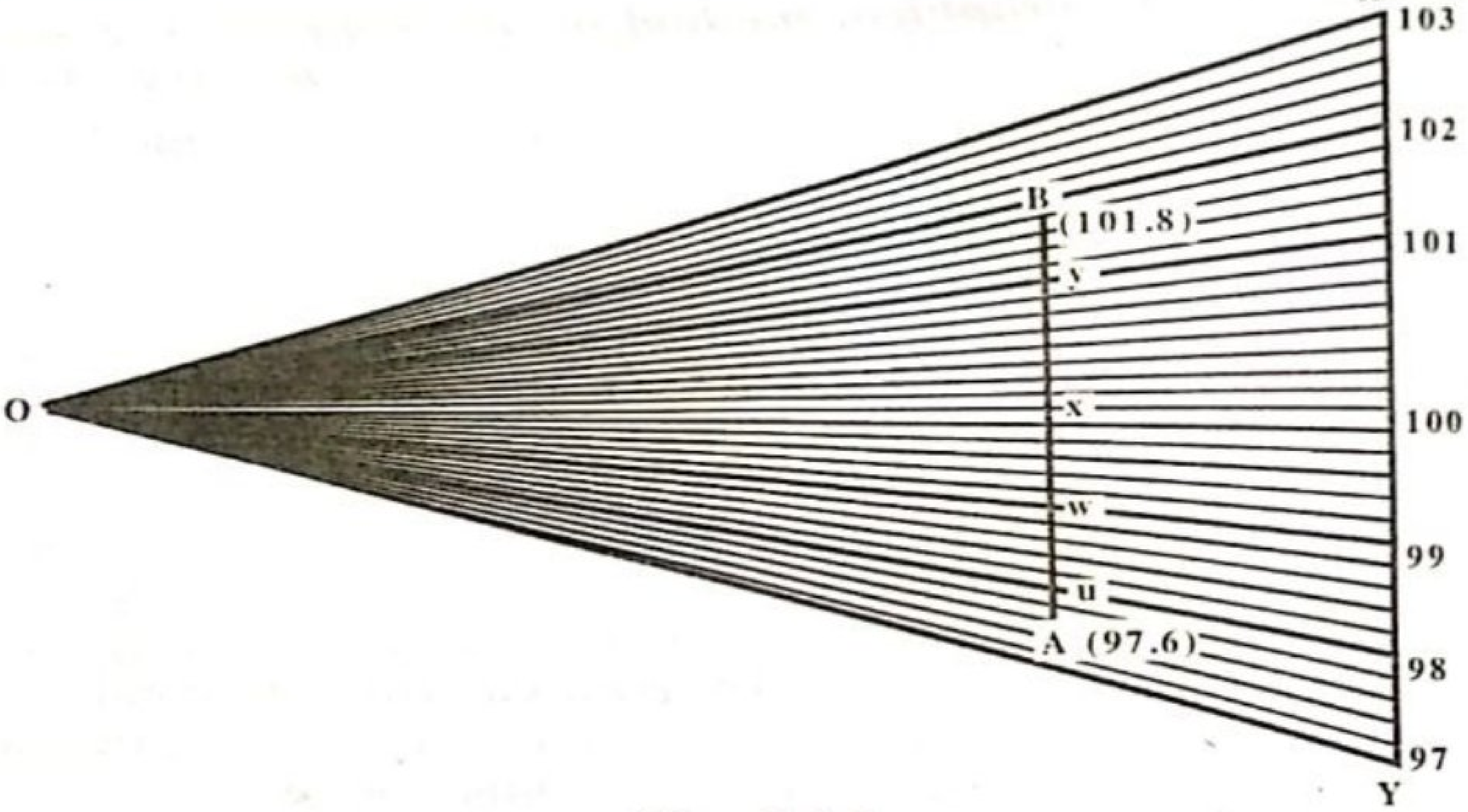


Fig. 3.14

PROFILE CROSS SECTIONING AND MEASUREMENT OF AREAS, VOLUMES, APPLICATION OF MEASUREMENTS IN QUANTITY COMPUTATIONS, SURVEY STATIONS

Q.16. Discuss various methods used for calculation of area.

#③

(R.G.P.V., Dec. 2008, 2010)

Or

Explain in brief the various methods of measurement of area by offsets from the base line. ***(R.G.P.V., June 2015)***

Ans. In surveying, area means area of plot or land. The area may be expressed in following units –

(i) Square metre (ii) Hectares (1 hectare = 10,000 m^2)

(iii) Square feet (iv) Acres (1 acre = 4840 sq. yard = 43,560 sq ft).

There are two methods of computation of area –

(i) Graphical method (ii) Instrumental method.

Graphical Method for Computation of Area – In graphical method, area is measured from –

(i) From field notes (ii) From plotted plan.

(i) Computation of Area from Field Notes – It requires two steps.

Step-1. The whole area of the field is divided into either triangles, rectangles or squares etc., and then the area is calculated as follows –

(a) Area of Triangle = $\sqrt{s(s-a)(s-b)(s-c)}$

where, a, b, c are the sides,

and $s = \frac{a+b+c}{2}$

where, s is the half perimeter.

or Area of Triangle = 1/2 (b × h)

where, b = Base and h = Altitude.

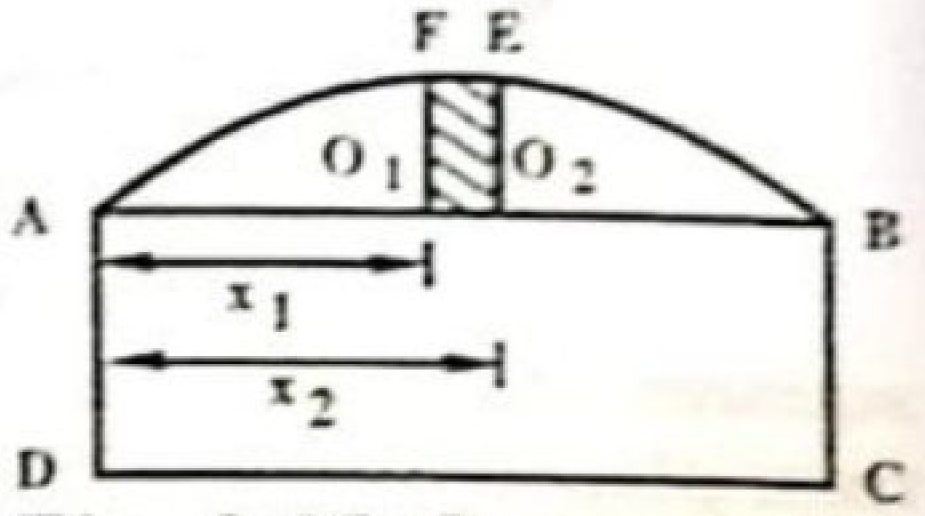


Fig. 3.15 Computation of Area

(b) Area of Rectangle = a × b

where a and b are the sides.

(c) Area of Square = a^2

where a is the side of the square.

(d) Area of Trapezium = 1/2 (a + b) × d

where a and b are the parallel sides, and d is the perpendicular distance between them.

Step-2. The area along the boundaries is calculated as follows –

A number of offsets are measured from the survey line to the nearest boundary line. The area of belts bounded by adjacent offsets are computed as follows –

Let O_1 = Offset length at a chainage x_1 from A along AB

O_2 = Offset length at a chainage x_2 from A along AB.

Then, the mean offset length = $\frac{O_1+O_2}{2}$

The distance between offsets = $x_2 - x_1$

∴ Area of the boundary area = $\frac{O_1+O_2}{2}(x_2-x_1)$

Similarly, the areas between all the belts bounded by offsets are calculated and added to geometrical areas of the field to obtained, total area. Hence,

Total area of the field = Area of geometrical figure + Boundary areas

= Area of ABCD + Area of ABEFA

(ii) Computation of Area from Plotted Plan – The area may be calculated in the two following ways –

Case (I) Considering the Entire Area – The complete area is divided into convenient shapes like, triangles, squares, as follows –

(a) By Dividing the Area into Triangles – Whole area is divided into number of triangles so as it equalise the irregular boundary line.

After that, the areas of these triangles are calculated. These area are then added to obtain the total area. (See fig. 3.16).

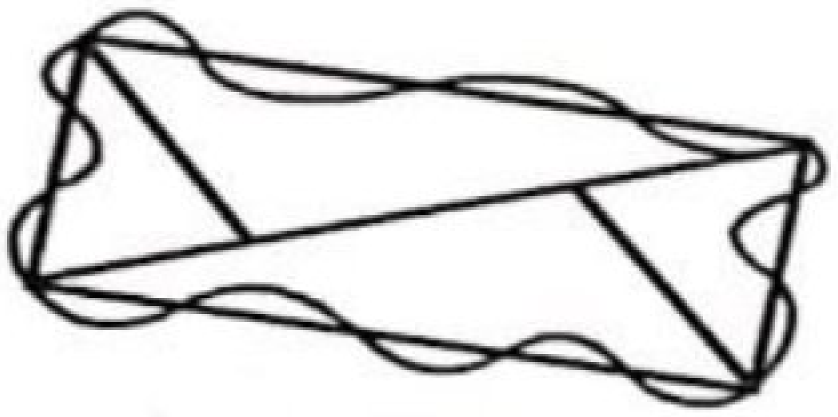


Fig. 3.16

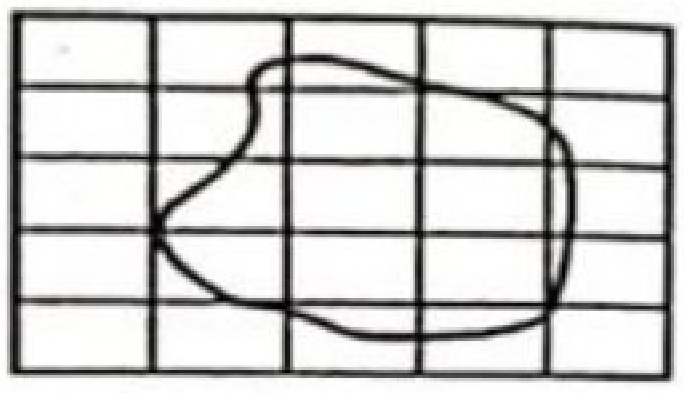


Fig. 3.17

(b) By Dividing the Area into Squares – In this method, squares of equal sizes are ruled out on a tracing paper, this tracing paper is then placed over the plan and numbers of squares are counted. The total area is then calculated by multiplying the number of squares by unit area of each square (Fig. 3.17).

(c) By Drawing Parallel Lines and Converting them to Rectangles – In this method, parallel lines are drawn on a tracing paper, this tracing paper is placed over the plan such that the area is enclosed between the two parallel lines at the top and bottom. Thus the area is divided into number of strips. The curved ends of the strips are replaced by rectangular lines, which forms the number of rectangles. The sum of the length of the rectangles is then calculated (Fig. 3.18).

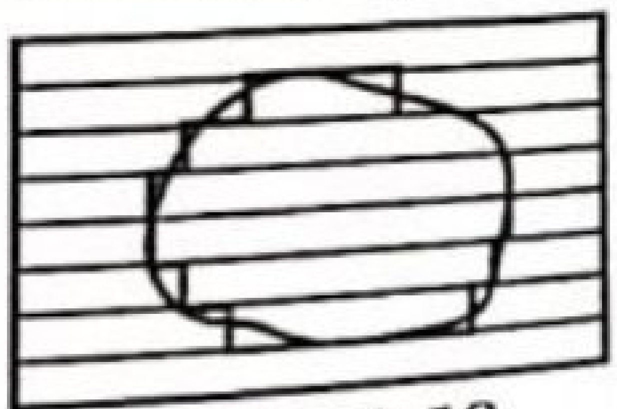


Fig. 3.18

So, required area = Σ Length of rectangles × Constant distance

Case (II) In this method, a large square or rectangle is formed within the area in the plan (Fig. 3.19). The middle area is calculated as usual, but boundary area is calculated according to one of the following rules –

(a) The mid-ordinate rule

(b) The average ordinate rule

(c) The trapezoidal rule

(d) Simpson's rule.

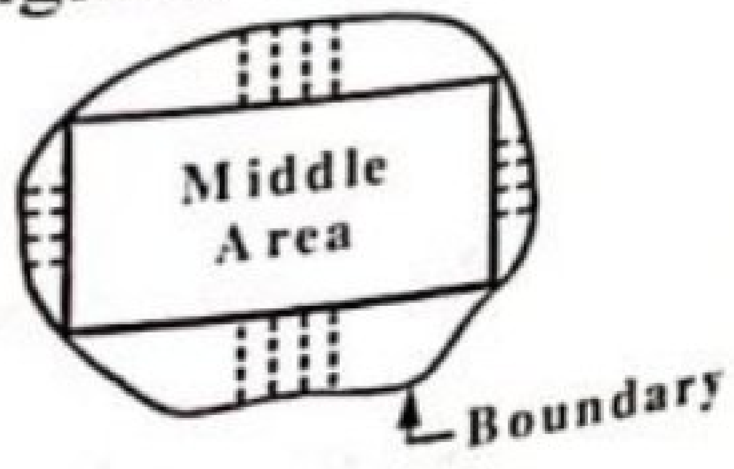


Fig. 3.19

(a) The Mid-ordinate Rule –

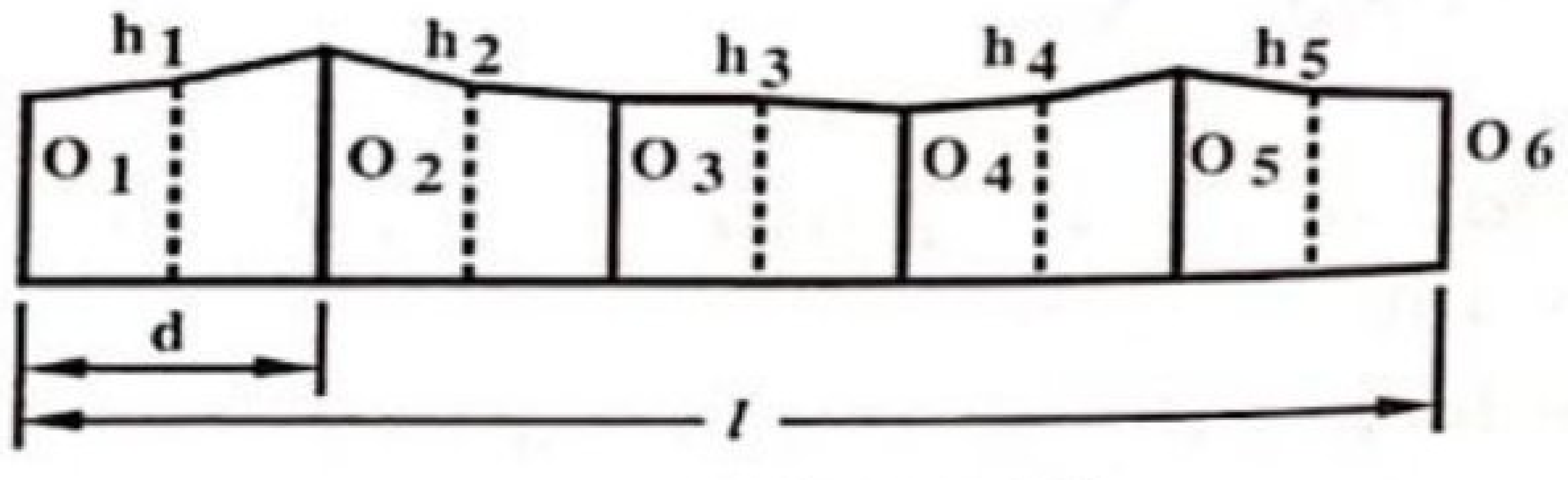


Fig. 3.20

Let, $O_1, O_2, O_3 \ldots\ldots\ldots O_n$ = Ordinates at equal intervals

l = Length of base line

d = Common distance between ordinates

$h_1, h_2, \ldots\ldots\ldots h_n$ = Mid-ordinates

$$\text{Area of plot} = h_1 \times d + h_2 \times d + \ldots\ldots\ldots\ldots + h_n \times d$$
$$= \mathbf{d \times (h_1 + h_2 + \ldots\ldots\ldots\ldots + h_n)}$$

So, Total area = Common distance × Sum of mid-ordinates

(b) The Average-ordinate Rule –

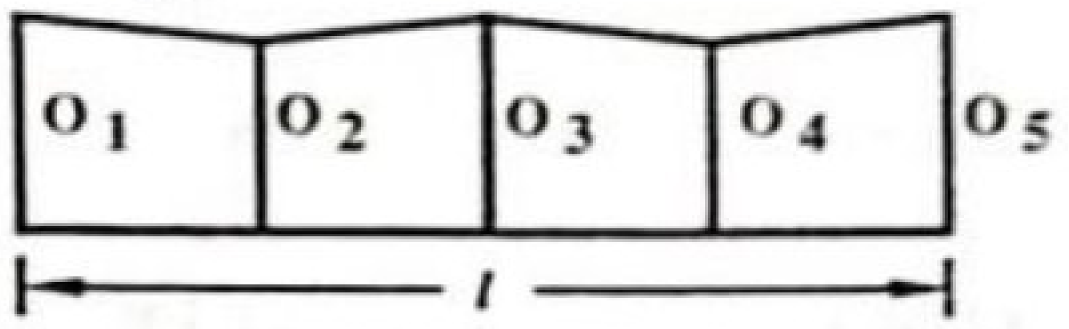


Fig. 3.21

Let, $O_1, O_2 \ldots\ldots\ldots\ldots O_n$ = Ordinates at regular intervals.

l = Length of base line

n = Number of divisions

n + 1 = Number of ordinates

$$\text{Total area} = \frac{\text{Sum of ordinates}}{\text{Number of ordinates}} \times \text{Length of base line}$$

$$\textbf{Total area} = \frac{\mathbf{O_1 + O_2 + \ldots\ldots\ldots O_n}}{\mathbf{n+1}} \times l$$

(c) The Trapezoidal Rule –

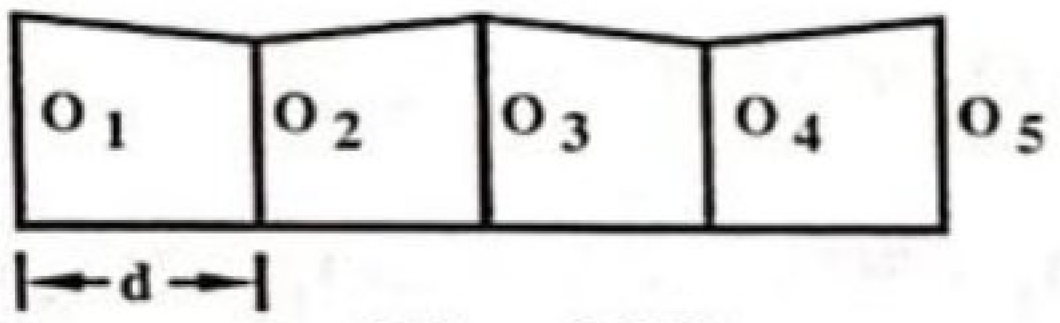


Fig. 3.22

Let, $O_1, O_2, \ldots\ldots\ldots\ldots O_n$ = Ordinates at equal intervals

d = Common distance

$$\text{Area of Ist trapezoid} = \frac{O_1 + O_2}{2} \times d$$

$$\text{Area of IInd trapezoid} = \frac{O_2 + O_3}{2} \times d$$

$$\text{Area of third trapezoid} = \frac{O_3 + O_4}{2} \times d$$

$$\text{Area of last trapezoid} = \left(\frac{O_{n-1} + O_n}{2}\right) d$$

$$\textbf{Total area} = \frac{\mathbf{d}}{\mathbf{2}} \mathbf{[O_1 + O_n + 2(O_1 + O_2 + O_3 + \ldots\ldots\ldots\ldots O_{n-1})]}$$

$$\text{Total area} = \frac{\text{Common distance}}{2} \text{ [First ordinate + Last ordinate}$$
$$\text{+ 2 (Sum of other ordinate)]}$$

(d) Simpson's Rule –

Assumption – The boundaries between the end of ordinates are assumed to form an parabolic arc whose axis is parallel to the offsets.

Let, O_1, O_2, O_3 are three ordinates

d = Common distance between ordinates

Area AFeDC = Area of trapezium AFDC + Area of segment FeDEF

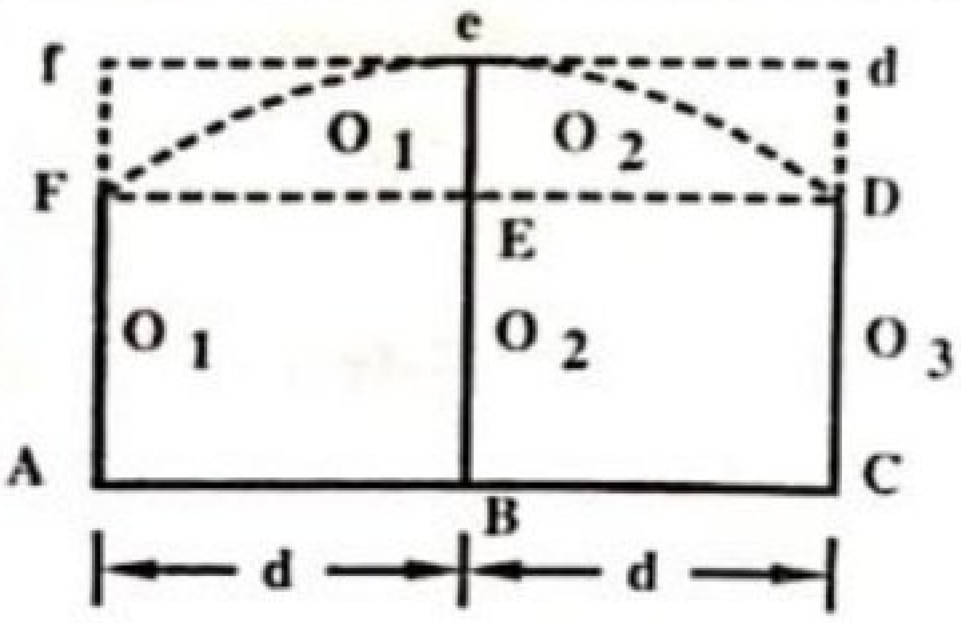


Fig. 3.23

Here, area of trapezium $= \dfrac{O_1+O_3}{2} \times 2d$

Area of segment = 2/3× Area of parallelogram FfdD

$$= \frac{2}{3} \times Ee \times 2d = \frac{2}{3} \times \left(O_2 - \frac{O_1+O_3}{2}\right) \times 2d$$

So, area of figure AFeDC or ordinates O_1 O_3 will be

$$= \frac{O_1+O_3}{2} \times 2d + \frac{2}{3} \times \left(O_2 - \frac{O_1+O_3}{2}\right) \times 2d$$

$$= (O_1+O_3)d + \frac{4}{3}O_2 d - \frac{2}{3}(O_1+O_3)d$$

$$= \frac{d}{3}(3O_1 + 3O_3 + 4O_2 - 2O_1 - 2O_3)$$

$$= \frac{d}{3}\ (O_1 + 4\ O_2 + O_3)$$

Similarly, the area between next two ordinates O_3 and O_5 will be given by equation

$$= \frac{d}{3}\ (O_3 + 4\ O_4 + O_5) \text{ and so on,}$$

$$\text{Total area } = \frac{d}{3}\ (O_1 + 4\ O_2 + 2\ O_3 + 4\ O_4 + \dots\dots\dots O_n)$$

$$= \frac{d}{3}\ [O_1 + O_n + 4\ (O_2 + O_4 + \dots\dots) + 2\ (O_3 + O_5 + \dots.]$$

$$= \frac{\text{Common distance}}{3}\ [(\text{First ordinate + Last ordinate}) + 4\ (\text{Sum of even ordinates}) + 2\ (\text{Sum of odd ordinates})]$$

The essential condition for Simpson's rule is the division of the required area should be in even numbers, or number of ordinates is odd.

Q.17. Differentiate between Trapezoidal and Simpson's rule.

Ans. Differences between Trapezoidal and Simpson's rule are given below –

S.No.	*Trapezoidal Rule*	*Simpson's Rule*
(i)	The boundary between the ordinates is considered straight.	The boundary between the ordinates is considered parabolic.
(ii)	There is no limitation, it is applicable for any number of ordinates.	The number of divisions should be even in this case.
(iii)	It gives approximate result.	It gives accurate result.
(iv)	The results obtained by trapezoidal rule does not effected because of boundary between the ordinates is considered straight.	The results obtained by Simpson's rule are greater or lesser than those obtained by using trapezoidal rule according as the curve of the boundary is convex or concave towards the base line.

Q.18. Write short note on various volume computation methods.
(R.G.P.V., Nov./Dec. 2007)

Or

Describe various formulae used for calculation of volume of earth work.
(R.G.P.V., June/July 2006, June 2009, 2010)

Ans. It is very necessary to work out the volume of earthwork involved in various civil engineering structures such as roads, railway, bridges etc. For work out the volume, the sectional areas of the cross-sections are first calculated cross-sections may be of following types –

(i) Level section
(ii) Two level section
(iii) There level section
(iv) Side hill two-level section
(v) Multi-level section.

After calculation of cross-sectional areas, the volume of the earth work is found out by following rules –

(i) The trapezoidal rule
(ii) The prismoidal rule.

Formulae for Calculation of Cross-sectional Area –

(i) Level Section – This formula is applicable when the ground is level along the transverse direction.

Cross-sectional area is given by

$$A = \frac{b+b+2sh}{2} \times h$$

$$A = (b + sh)\,h$$

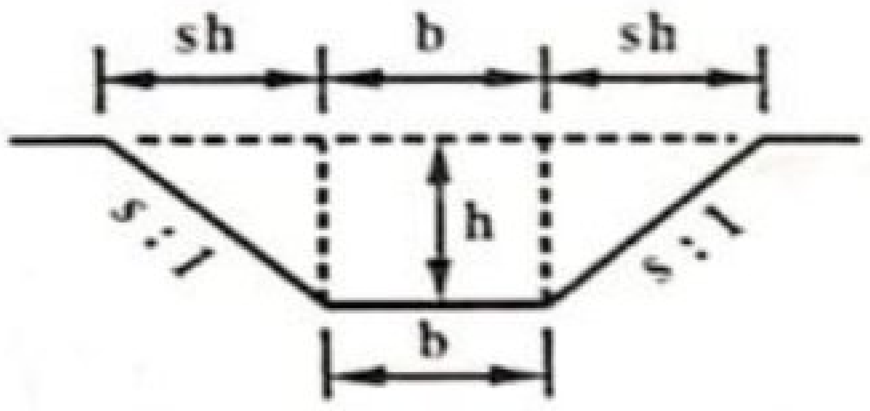


Fig. 3.24

where,
b = Width of the formation
h = Depth of the section
s = Side slope.

(ii) Two Level Section – This formula is applicable when the ground surface has a transverse slope.

Cross-sectional area is given by

$$A=\frac{1}{2}\left[\left(\frac{b}{2s}+h\right)(b_1+b_2)-\frac{b^2}{2s}\right]$$

In which, $b_1=\frac{b}{2}+\frac{ns}{n-s}\times\left(h+\frac{b}{2n}\right)$

$$b_2=\frac{b}{2}+\frac{ns}{n+s}\times\left(h-\frac{b}{2n}\right)$$

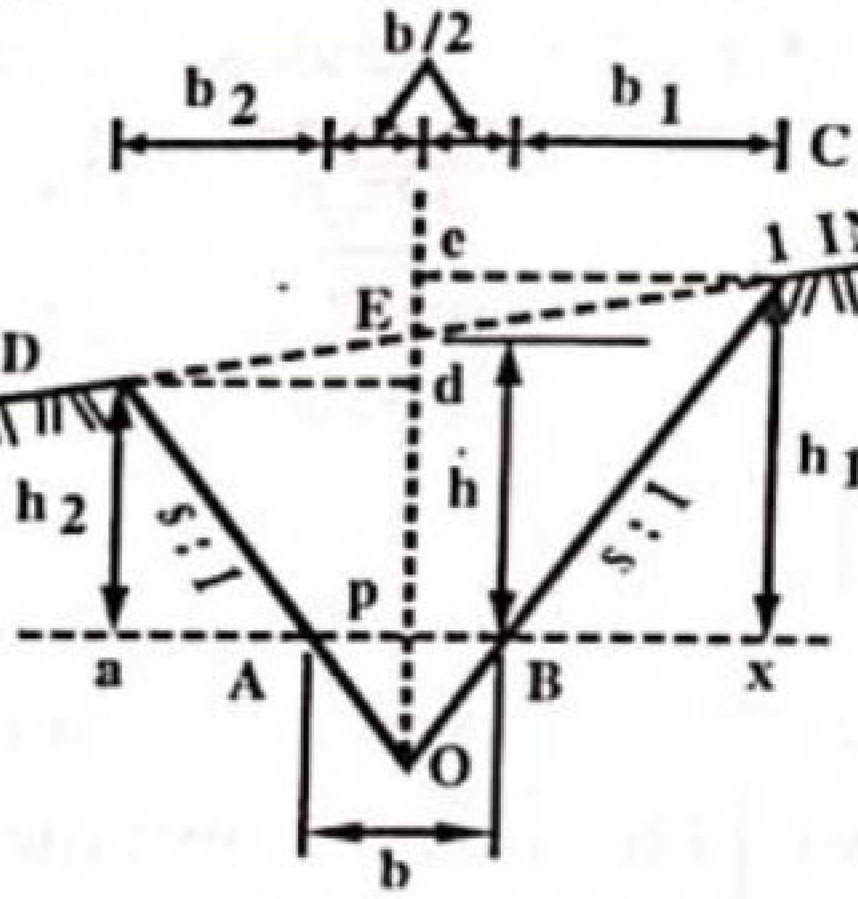


Fig. 3.25

where, b = Width of the formation

n = Transverse slope, i.e., n horizontal to 1 vertical

s = Side slope, i.e., s horizontal to 1 vertical

h = Depth of the section

b_1 and b_2 = Side widths, i.e., the horizontal distance from the centre to the intersection of the side slopes with the original ground surfaces.

(iii) Three Level Section – It is applicable when the transverse slope is not uniform.

$$\text{Area}=\left[\frac{h}{2}(b_1+b_2)+\frac{b}{4}(h_1+h_2)\right]$$

In which $h_1=h+\frac{b_1}{n_1}$ and $h_2=h-\frac{b_2}{n_2}$

$$b_1=\frac{n_1 s}{n_1-s}\left(h+\frac{b}{2s}\right)$$

and $$b_2=\frac{n_2 s}{n_2+s}\left(h+\frac{b}{2s}\right)$$

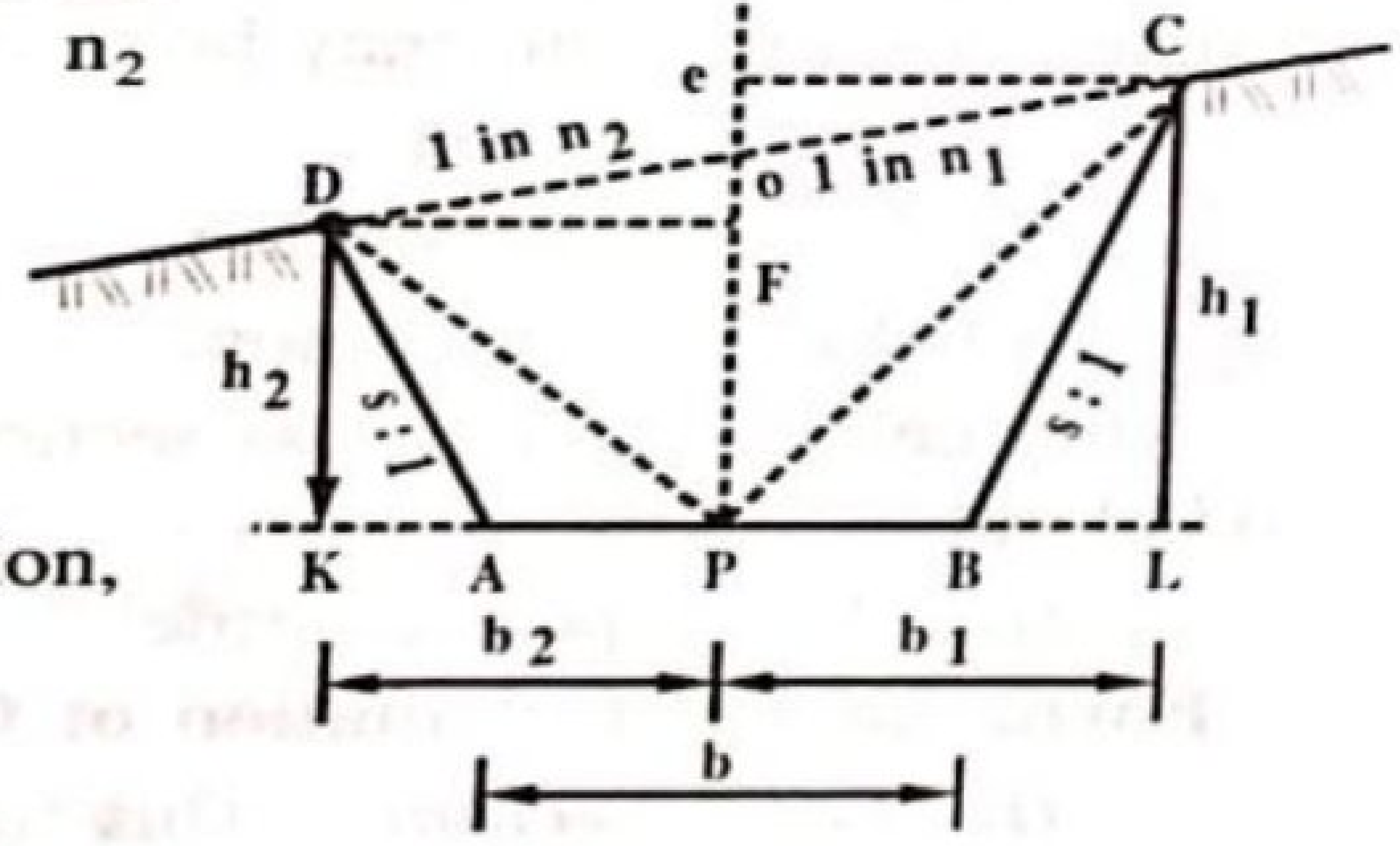


Fig. 3.26

where, h = Width of the formation,

s = Side slope

n_1 and n_2 = Transverse slope,

h = Depth of the section

b_1 and b_2 = Side widths.

Formulae for Calculation of Volume – After finding out the area, the volume is obtained by the following rules –

D = Common distance between sections

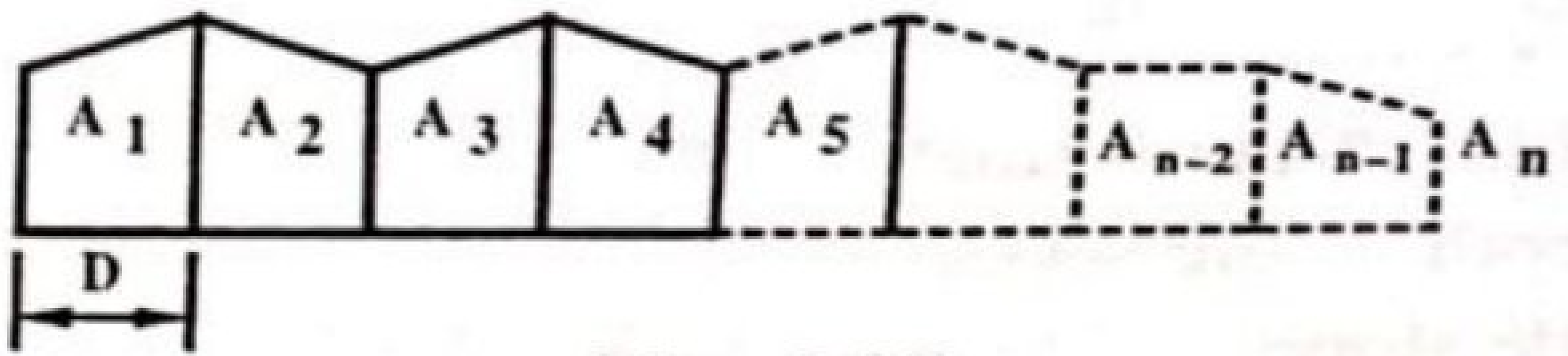


Fig. 3.27

(i) ***Trapezoidal Rule*** – Volume (cutting or filling),

$$V = \frac{D}{2}\ [A_1 + A_n + 2\ (A_2 + A_3 + \dots\dots\dots A_{n-1})]$$

So, $\quad \text{Volume} = \frac{\text{Common distance}}{2} \times$ [Area of first section + Area of last section + 2 (Sum of area of other sections)]

(ii) ***Prismoidal Formula*** – Volume (cutting or filling),

$$V = D/3\ [A_1 + A_n + 4\ (A_2 + A_4 + A_{n-1}) + 2\ (A_3 + A_5 + \dots\dots\dots A_{n-2})]$$

So, $\quad \text{Volume} = \frac{\text{Common distance}}{3} \times$ [Area of first section + Area of last section + 4 (Sum of areas of even sections) + 2 (Sum of areas of odd sections)]

This Prismoidal formula is used whenever there are an odd number of sections. If there are even number of sections then trapezoidal rule is applied.

Q.19. Explain methods for measuring the area and volume.

(R.G.P.V., April 2009, Dec. 2012)

Or

List out with details of various methods to calculate area and volume in surveying. ***(R.G.P.V., Dec. 2015)***

Ans. Refer Q.16 and Q.18.

Q.20. With reference to civil engineering practice explain what is meant by the prismoidal rule. ***(R.G.P.V., June 2015)***

Ans. Refer Q.18 (ii) under heading formulae for calculation of volume.

Q.21. With reference to civil engineering practice explain what is meant by the following –

(i) Trapezoidal and prismoidal rules

(ii) Prismoidal corrections.

(R.G.P.V., Dec. 2013)

Ans. (i) Trapezoidal and Prismoidal Rules – Refer Q.18.

(ii) Prismoidal Corrections – The volume which is obtained by prismoidal formula is more accurate than the volume which is obtained by the trapezoidal rule. However, it is more inconvenient to use prismoidal formula than the trapezoidal rule. Instead of calculating the volume by the prismoidal formula, it is generally more convenient to calculate the volume by the trapezoidal rule and apply a correction is known the prismoidal correction.

The volume obtained by the trapezoidal formula is always greater than the volume obtained by the prismoidal formula. The prismoidal correction is negative. The correction is easily calculated because it requires no information other than that required for the trapezoidal rule.

The prismoidal correction is also called as prismoidal excess. The general expression for the prismoidal correction (C_p) can be given as.

$$C_p = \text{Volume by trapezoidal rule-volume by the prismoidal formula}$$

$$= \frac{D}{2}(A_1 + A_2) - \frac{D}{6}(A_1 + 4A_m + A_2)$$

$$= \frac{D}{6}(3A_1 + 3A_2 - A_1 - 4A_m - A_2) = \frac{D}{3}(A_1 - 2A_m + A_2)$$

The exact value of C_p will depend upon the type of section.

Q.22. Explain survey stations. ***(R.G.P.V., Dec. 2012)***

Ans. Refer Q.13, Unit-II.

Q.23. What are the selection criteria of survey station ? ***(R.G.P.V., Dec. 2014)***

Ans. Refer Q.14, Unit-II.

Q.24. What do you understand by survey stations ? Discuss requirements of a good survey stations. ***(R.G.P.V., June 2013)***

Ans. **Survey Stations** – Refer Q.13, Unit-II.

Requirements of a Good Survey Station – Refer Q.14, Unit-II.

NUMERICAL PROBLEMS

Prob.1. Following perpendicular offsets were taken from a chain-line to an irregular boundary.

Chainage (m)	*0*	*10*	*25*	*42*	*50*	*75*
Offset (m)	*12.5*	*26.2*	*28.7*	*32.6*	*21.9*	*29.0*

Calculate area between the chain line, the boundary and the end offsets using trapezoidal method. ***(R.G.P.V., June 2012)***

Sol.

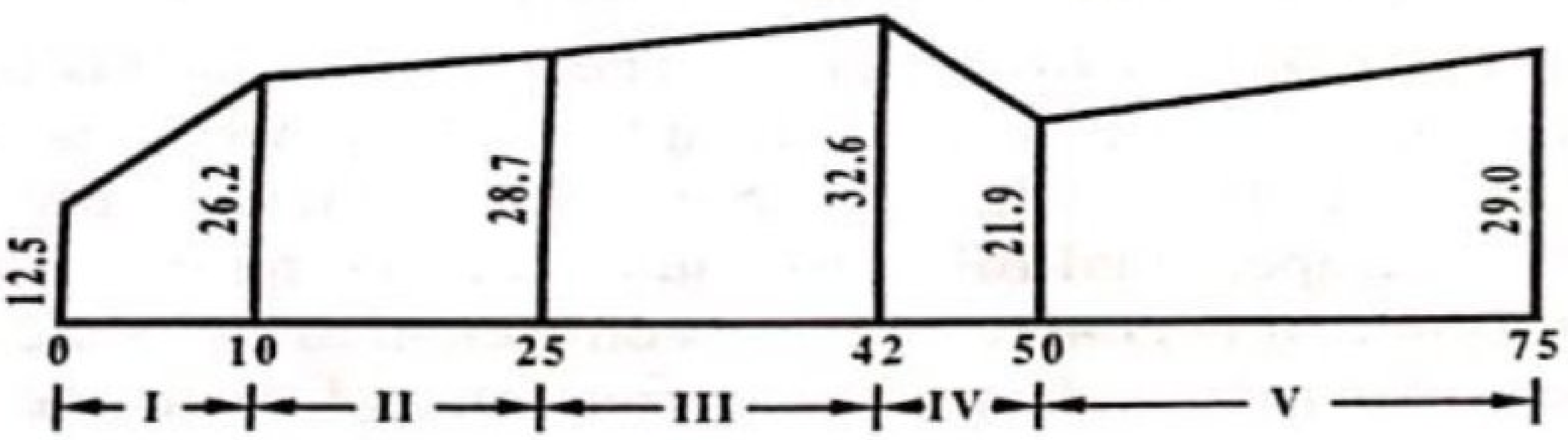


Fig. 3.28

Area by Trapezoidal Rule –

$$A = \frac{\text{Common distance}}{2}[\text{First ordinate} + \text{Last ordinate} + 2\,(\text{Sum of other ordinates})]$$

$$A_1 = \frac{10}{2}[12.5 + 26.2] = 193.5\ \text{m}^2, \quad A_2 = \frac{15}{2}[26.2 + 28.7] = 411.75\ \text{m}^2$$

$$A_3 = \frac{17}{2}[28.7 + 32.6] = 521.05\ \text{m}^2, \quad A_4 = \frac{8}{2}[32.6 + 21.9] = 218.00\ \text{m}^2$$

$$A_5 = \frac{25}{2}[21.9 + 29.0] = 636.25\ \text{m}^2$$

Total area = 193.5 + 411.75 + 521.05 + 218 + 636.25
= **1980.55 m²**

Ans.

Prob.2. A series of offsets were taken from a chain line to a curved boundary line at intervals of 15 m in the following order – 0.00, 2.60, 3.85, 3.98, 4.12, 4.95, 5.80 metre. Compute the area between the chain line and the curved boundary the end offset by –

(i) Simpson's rule (ii) Trapezoidal rule.

(R.G.P.V., June 2016)

Sol.

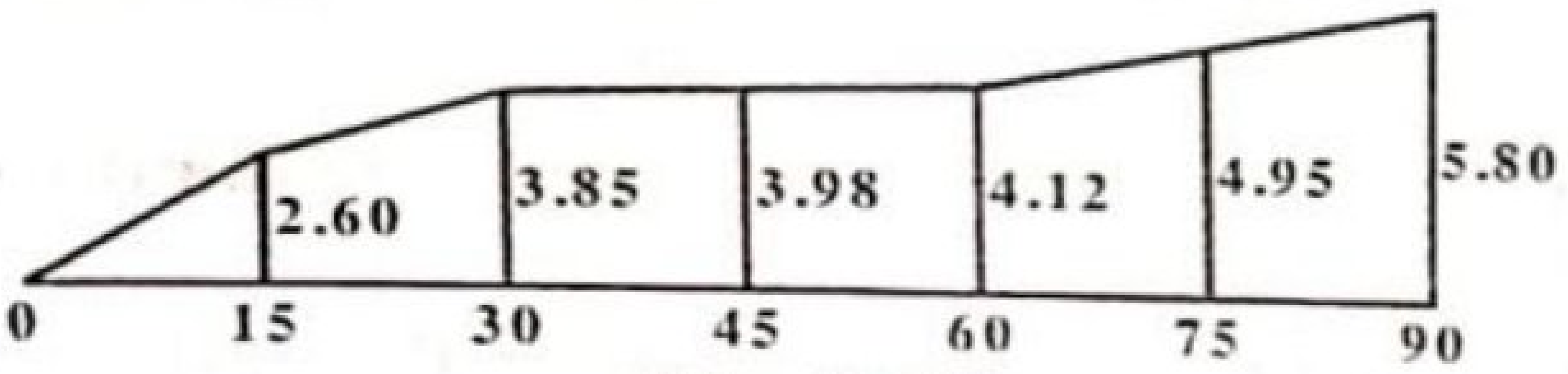


Fig. 3.29

(i) Simpson's Rule –

$$\text{Total area} = \frac{d}{3}[O_1 + O_n + 4(O_2 + O_4 + \ldots) + 2(O_3 + O_5 + \ldots)]$$

$$= \frac{15}{3}[0.00 + 5.80 + 4(2.60 + 3.98 + 4.95) + 2(3.85 + 4.12)]$$

$$= \mathbf{339.3\ m^2}$$

Ans.

(ii) Trapezoidal Rule –

$$\text{Total area} = \frac{d}{2}[O_1 + O_n + 2(O_2 + O_3 + O_4 + \ldots)]$$

$$= \frac{15}{2}[0.00 + 5.80 + 2(2.60 + 3.85 + 3.98 + 4.12 + 4.95)]$$

$$= \mathbf{336\ m^2}$$

Ans.

Prob.3. A series of offsets were taken from a chain line to a curved boundary line at intervals of 15 m in the following order

0, 2.65, 3.80, 4.65, 3.60, 4.95, 5.85 m

Compute the area between the chain line and the curved boundary and the end offsets by –

(i) Trapezoidal rule (ii) Simpson's rule.

(R.G.P.V., June/July 2006, Dec. 2011)

Sol. Similar as Prob.2.

Prob.4. The following offsets were taken from a chain line to hedge–

Distance (m)	*0*	*20*	*40*	*60*	*80*	*120*	*160*	*220*	*280*
Offset (m)	*9.4*	*10.8*	*13.6*	*11.2*	*9.6*	*8.4*	*7.5*	*6.3*	*4.6*

Compute the area included between the chain line and the offset by

(i) Mid-ordinate rule (ii) Simpson's rule.

(R.G.P.V., June 2015)

Sol.

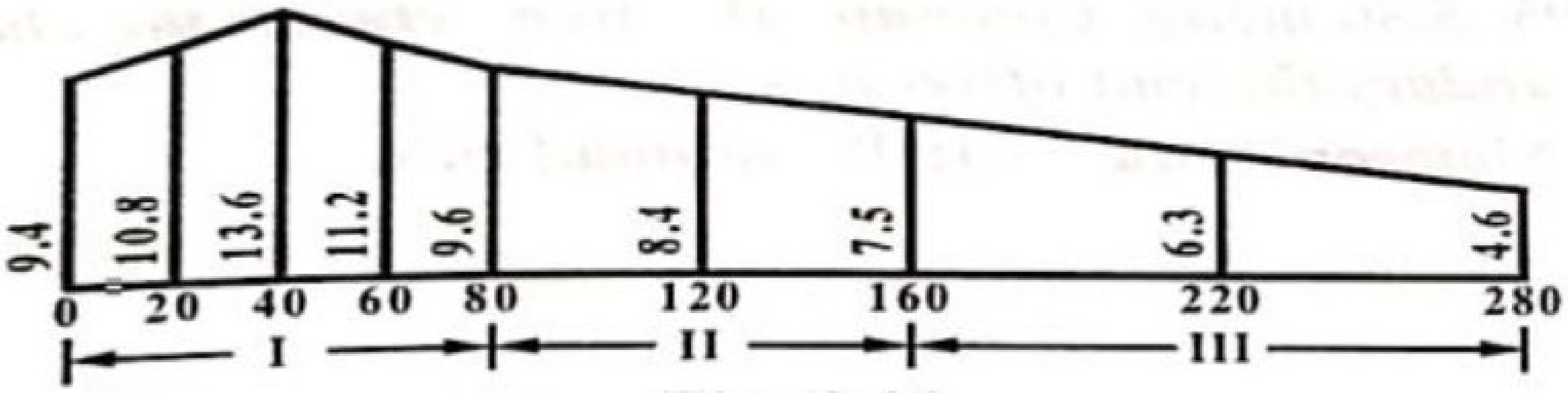


Fig. 3.30

Here, the interval between the offsets are not regular throughout the length. So, the section is divided into three parts.

Let, A_1, A_2, A_3 in which $d_1 = 20$ m, $d_2 = 40$ m, $d_3 = 60$ m

(i) Area by Mid-ordinate Rule –

Area of part I,

$$h_1 = \frac{9.4+10.8}{2} = 10.1 \text{ m}, \qquad h_2 = \frac{10.8+13.6}{2} = 12.2 \text{ m}$$

$$h_3 = \frac{13.6+11.2}{2} = 12.4 \text{ m}, \qquad h_4 = \frac{11.2+9.6}{2} = 10.4 \text{ m}$$

Required area for part I,

$$A = 20(10.1 + 12.2 + 12.4 + 10.4) = 902 \text{ m}^2$$

Area of part II,

$$h_5 = \frac{9.6+8.4}{2} = 9 \text{ m}, \qquad h_6 = \frac{8.4+7.5}{2} = 7.95 \text{ m}$$

Required area for part II,

$$A_2 = 40(9 + 7.95) = 678 \text{ m}^2$$

Area of part III.

$$h_7 = \frac{7.5+6.3}{2} = 6.9 \text{ m}, \qquad h_8 = \frac{6.3+4.6}{2} = 5.45 \text{ m}$$

Required area for part III

$$A_3 = 60(6.9 + 5.45) = 741 \text{ m}^2$$

$$\text{Total area} = A_1 + A_2 + A_3$$
$$= 902 + 678 + 741 = \mathbf{2321 \text{ m}^2} \qquad \text{Ans.}$$

(ii) Area by Simpson's Rule –

$$A = \frac{\text{Common distance}}{3}[\text{First ordinate + Last ordinate} + 4\text{ (Sum of even ordinates} + 2\text{ (Sum of odd ordinates)}]$$

$$A_1 = \frac{20}{3}[9.4 + 9.6 + 4(10.8 + 11.2) + 2(13.6)] = 894.67 \text{ m}^2$$

$$A_2 = \frac{40}{3}[9.6 + 7.5 + 4(8.4)] = 676 \text{ m}^2$$

$$A_3 = \frac{60}{3}[7.5 + 4.6 + 4(6.3)] = 746 \text{ m}^2$$

$$\text{Total area} = A_1 + A_2 + A_3 = 894.67 + 676 + 746 = \mathbf{2316.67 \text{ m}^2} \qquad \text{Ans.}$$

Prob.5. The following perpendicular offsets in m are measured from a straight line to an irregular boundary at regular intervals of 10 m.

$h_1 = 8.25$, $h_2 = 13.85$, $h_3 = 12.25$, $h_4 = 10.85$, $h_5 = 12.25$, $h_6 = 13.60$, $h_7 = 15.25$, $h_8 = 16.85$, $h_9 = 14.95$, $h_{10} = 17.35$, $h_{11} = 20.05$, $h_{12} = 15.90$, $h_{13} = 12.25$, $h_{14} = 12.00$. Compute the area included between the straight line, the irregular boundary by

(i) Trapezoidal rule

(ii) Simpson's one-third rule (a) using h_1 as the first offset, (b) using h_{14} as the last offset.

(R.G.P.V., Dec. 2013)

Sol.

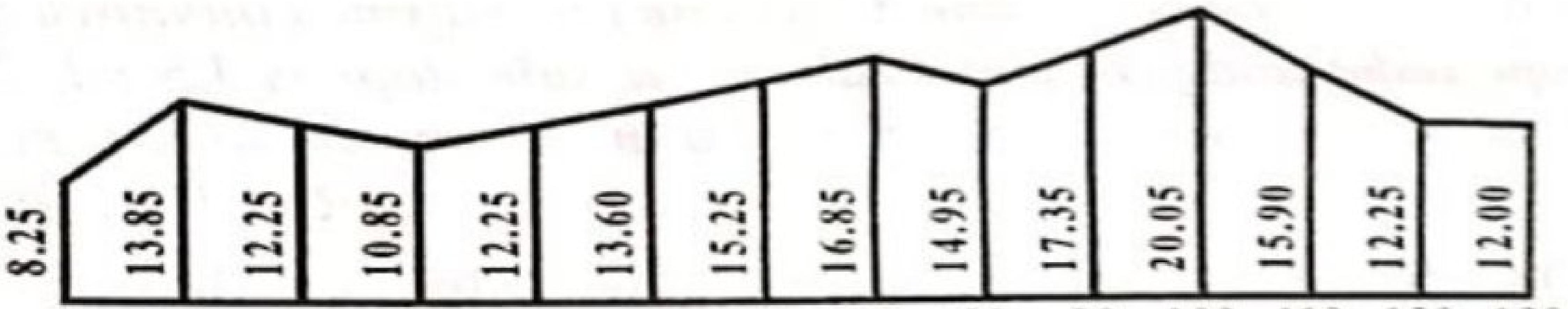


Fig. 3.31

(i) Area by Trapezoidal Rule –

$$A = \frac{D}{2}[\text{First ordinate + Last ordinate} + 2(\text{Sum of other ordinates})]$$

$$= \frac{10}{2}\,[8.25 + 12.00 + 2(13.85 + 12.25 + 10.85 + 12.25 + 13.60 + 15.25 + 16.85 + 14.95 + 17.35 + 20.05 + 15.90 + 12.25)]$$

$$= \frac{10}{2}[8.25 + 12.00 + 350.8] = \frac{10}{2} \times 371.05 = \mathbf{1855.25\ m^2} \qquad \textbf{Ans.}$$

(ii) Area by Simpson's Rule – If Simpson's rule is applied, the number of ordinates must be odd. But here number of ordinates are even, so Simpson's rule is applied from h_1 to h_{13} and the area between h_{13} and h_{14} will be found out by the trapezoidal rule.

$$A_1 = \frac{D}{3}\begin{bmatrix}\text{First ordinate} + \text{Last ordinate} + 4(\text{Sum of even ordinate}) \\ + 2(\text{Sum of odd ordinate})\end{bmatrix}$$

$$= \frac{D}{3}\begin{bmatrix}h_1 + h_{13} + 4(h_2 + h_4 + h_6 + h_8 + h_{10} + h_{12}) \\ + 2(h_3 + h_5 + h_7 + h_9 + h_{11})\end{bmatrix}$$

$$= \frac{10}{3}\begin{bmatrix}8.25 + 12.25 + 4(13.85 + 10.85 + 13.60 + 16.85 + 17.35 + 15.90) \\ + 2(12.25 + 12.25 + 15.25 + 14.95 + 20.05)\end{bmatrix}$$

$$= \frac{10}{3}[8.25 + 12.25 + 353.6 + 149.5] = 1745.33\ m^2$$

$$A_2 = \frac{D}{2}[h_{13} + h_{14}] = \frac{D}{2}[12.25 + 12.00] = 121.25\ m^2$$

$$A = A_1 + A_2 = 1745.33 + 121.25 = \mathbf{1866.58\ m^2} \qquad \textbf{Ans.}$$

Prob.6. The following perpendicular offsets were taken at 20 m intervals from a base line to an irregular boundary line.

5.9, 12.4, 16.5, 15.3, 18.4, 20.9, 24.9, 21.8, and 19.2 metres. Calculate the area enclosed between the base line the irregular boundary line and the first and last offsets by –

(i) Trapezoidal rule (ii) Simpson's rule.

(R.G.P.V., Dec. 2012)

Sol. Similar as Prob.5.

Prob.7. A railway embankment is 12 m wide. The ground is level in the direction transverse to the centre line. Calculate the volume contained in a 100 m length by trapezoidal and prismoidal rule, if the side slope is 1.5 : 1. The centre height at 20 m interval are 3.7 m, 2.6 m, 4.0 m, 3.4 m, 2.8 m, 3.0 m, 2.2 m.

(R.G.P.V., June 2013)

Sol. The cross-sectional areas are calculated by $A = (b + sh)\,h$

$$A_1 = (12 + 1.5 \times 3.7)\,3.7 = 64.935\ m^2$$
$$A_2 = (12 + 1.5 \times 2.6)\,2.6 = 41.34\ m^2$$
$$A_3 = (12 + 1.5 \times 4.0)\,4.0 = 72.00\ m^2$$
$$A_4 = (12 + 1.5 \times 3.4)\,3.4 = 58.14\ m^2$$
$$A_5 = (12 + 1.5 \times 2.8)\,2.8 = 45.36\ m^2$$

$$A_6 = (12 + 1.5 \times 3.0)\ 3.0 = 49.50\ m^2$$
$$A_7 = (12 + 1.5 \times 2.2)\ 2.2 = 33.66\ m^2$$

(i) Volume According to Trapezoidal Rule –

$$V = \frac{20}{2}\begin{bmatrix} 64.935 + 33.66 + 2(41.34 + 72.00 \\ + 58.14 + 45.36 + 49.50) \end{bmatrix} = \mathbf{6312.75\ m^3} \qquad \textbf{Ans.}$$

(ii) Volume According to Prismoidal Rule –

$$V = \frac{20}{3}\begin{bmatrix} 64.935 + 33.66 + 4(41.34 + 58.14 + 49.50) \\ + 2(72.00 + 45.36) \end{bmatrix} = \mathbf{6194.90\ m^3}\textbf{Ans.}$$

④ # ***Prob.8. A road embankment is 8 m wide and 200 m in length at the formation level, with a side slope of 1.5 : 1. The embankment has a rising gradient of 1 in 10 m. The ground levels at every 50 m along the centre line are as follows –***

Distance (m)	*0*	*50*	*100*	*150*	*200*
R.L.(m)	*164.5*	*165.2*	*166.8*	*167*	*167.2*

The formation level of zero chainage is 166 m. Calculate the volume of earth work by using Trapezoidal rule and Prismoidal rule.

(R.G.P.V., Dec. 2014)

Sol. Since the embankment level is to have a rising gradient of 1 in 10 m. The formation level at every section can be easily calculated as tabulated below –

Distance	*R.L.*	*F.L.*	*Filling*
0	164.5	166	1.5
50	165.2	167	1.8
100	166.8	168	1.2
150	167	169	2
200	167.2	170	2.8

The area of section is given by

$$A = (b + sh)\ h = (8 + 1.5\ h)\ h$$

where $b = 8$ m, $s = 1.5$

$$A_1 = (8 + 1.5 \times 1.5) \times 1.5 = 15.37\ m^2$$
$$A_2 = (8 + 1.5 \times 1.8) \times 1.8 = 19.26\ m^2$$
$$A_3 = (8 + 1.5 \times 1.2) \times 1.2 = 11.76\ m^2$$
$$A_4 = (8 + 1.5 \times 2) \times 2 = 22\ m^2$$
$$A_5 = (8 + 1.5 \times 2.8) \times 2.8 = 34.16\ m^2$$

Volume by Trapezoidal rule is given by

$$V = \frac{D}{2}[A_1 + A_n + 2 \times (A_2 + A_3 + ... + A_{n-1})]$$

$$= \frac{50}{2}[15.37 + 34.16 + 2 \times (19.26 + 11.76 + 22)]$$

$$= \mathbf{3889.25\ m^3}$$ **Ans.**

Volume by Prismoidal rule is given by

$$V = \frac{D}{3}[(A_1 + A_n) + 4 \times \text{Area of even distance} + 2 \times \text{Area of odd distance}]$$

$$V = \frac{50}{3}[15.37 + 34.16 + 4 \times (19.26 + 22) + 2 \times 11.76] = \mathbf{3968.17\ m^3}$$ **Ans.**

Prob.9. A rectangular plot abcd forms the plane of a pit for borrowing earth from it. e is point of intersection of the diagonals. Calculate volume of excavation using following data –

Point	*a*	*b*	*c*	*d*	*e*
Original Levels (m)	*45.2*	*49.8*	*51.2*	*47.2*	*52.0*
Final Levels (m)	*38.6*	*39.8*	*42.6*	*40.8*	*42.5*

Provided length ab = 50 m, bc = 80 m. ***(R.G.P.V., June 2014)***

Sol. Area of each triangle = $\frac{1}{2} \times 50 \times 40 = 1000\,\text{m}^2$.

Take the vertices of each triangle and find the mean depth at each triangle. Thus,

Depth of cutting at a = 45.2 – 38.6 = 6.6 m
Depth of cutting at b = 49.8 – 39.8 = 10.0 m
Depth of cutting at c = 51.2 – 42.6 = 8.6 m
Depth of cutting at d = 47.2 – 40.8 = 6.4 m
Depth of cutting at e = 52.0 – 42.5 = 9.5 m

Now volume of any truncated triangular prism is given by

$$V = \text{Average height} \times A = hA$$

For the triangular prism abe

$$h = \frac{6.6 + 10 + 9.5}{3} = 8.7\,\text{m}$$

$$\therefore \quad V_1 = 8.7 \times 1000 = 8700\ \text{m}^3$$

For the prism bce,

$$h = \frac{10 + 8.6 + 9.5}{3} = 9.367\,\text{m}$$

$$\therefore \quad V_2 = 9.367 \times 1000 = 9367\ \text{m}^3$$

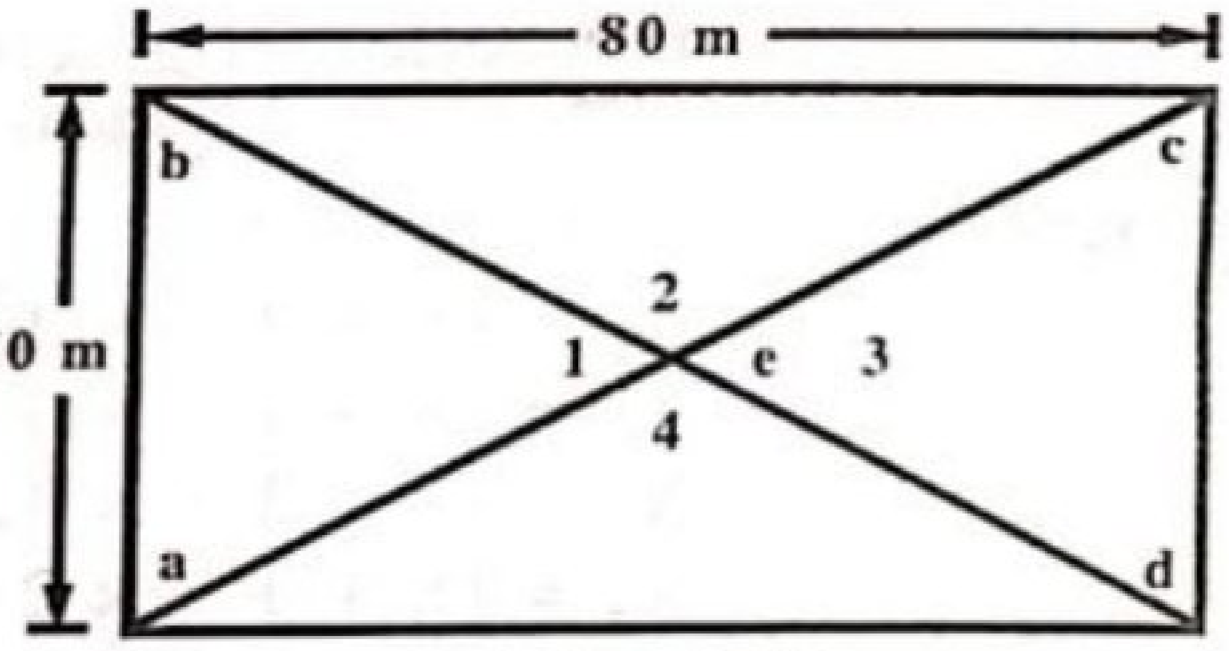


Fig. 3.32

For the prism cde,

$$h = \frac{8.6 + 6.4 + 9.5}{3} = 8.167$$

$$\therefore \quad V_3 = 8.167 \times 1000 = 8167\ \text{m}^3$$

For the prism dae,

$$h = \frac{6.4 + 6.6 + 9.5}{3} = 7.5\,\text{m}$$

$$\therefore \quad V_4 = 7.5 \times 1000 = 7500\ \text{m}^3$$

$$\therefore \quad \text{Total volume} = V_1 + V_2 + V_3 + V_4$$

$$= 8700 + 9367 + 8167 + 7500 = 33734\ \text{m}^3$$

Alternatively, the total volume may be obtained. Thus,

$$V = \frac{A}{3}\,(1\Sigma h_1 + 2\Sigma h_2 + 3\Sigma h_3 + \ldots\ldots + 8\Sigma h_8)$$

Here $1\Sigma h_1 = 0$

$$2\Sigma h_2 = 2\,(6.6 + 10 + 8.6 + 6.4) = 63.2$$

(Since height of every outer corner is utilized in two triangles)

$3\Sigma h_3, 5\Sigma h_5, 6\Sigma h_6, 7\Sigma h_7$ and $8\Sigma h_8$ are each zero.

$$4\Sigma h_4 = 4(9.5) = 38$$

Substituting the values in above equation, we get

$$V = \frac{1000}{3} \times (63.2 + 38) = 33733\ \text{m}^3$$ Ans.

INTRODUCTION OF REMOTE SENSING AND ITS APPLICATIONS

Q.25. Describe briefly the remote sensing and its applications.
(R.G.P.V., Dec. 2013)

Or

Define and describe remote sensing. Explain its applications in various fields. ***(R.G.P.V., June 2010, Dec. 2011)***

Or

What are the various applications of remote sensing in civil engineering? Explain briefly. ***(R.G.P.V., June 2011)***

Or

⑤ ***What do you understand by remote sensing ? What are its various applications ?*** ***(R.G.P.V., June 2012)***

Or

Explain the term 'Remote sensing' in detail. What are the various applications of remote sensing ? ***(R.G.P.V., Dec. 2012)***

Or

State various applications of remote sensing. ***(R.G.P.V., Dec. 2014)***

Or

Write an explanatory note on applications of remote sensing.
(R.G.P.V., June 2014)

Or

What is remote sensing ? Give its applications to civil engineering.
(R.G.P.V., Dec. 2015)

Or

Define and describe remote sensing and its various applications in civil engineering.
(R.G.P.V., June 2016)

Ans. Remote sensing is defined as collecting datas and informations about a target without coming in contact with it. It is the study of an object from a distance to know about the chemical and physical characteristics of objects. Human eyes are the very good example of remote sensing. In fact, sight, smell and hearing all are the forms of the remote sensing.

The technique in general consists in obtaining information about an object or phenomenon, situated at a long distance, by virtue of either reflected or emitted electro-magnetic radiation from such an object or phenomenon by means of sensors from space platform.

Remote sensing has wide applications in agriculture, forest development Geology and Archaeology and in the study of hazards such as earthquakes, land slides and subsidence of land etc. Exploration of water resources, analysis of land use and land cover are possible with the techniques of remote sensing.

Remote sensing is very much useful for aircrafts and satellites. Data required are collected by radar, camera and other sophisticated sensors. It includes all the methods of obtaining pictures and electromagnetic records of the earth's surface from a distance. Most of the remote sensing methods used reflected infrared bands, thermal infrared bands, and microwave portion of the eletromagnetic spectrum.

There are various applications of remote sensing systems, such as –

Remote sensing is very useful for finding out the datas necessary for making decisions and formulations of policy, land uses and resource development. It monitores the earth's natural and other resources and of determining the impact of man's activities on air, water and land. It is useful for detecting forest fires, before the smoke appears, detecting presence of pollutants, useful for geological and survey work.

Remote sensing techniques has a wide application in the various fields such as civil engineering fields, geological investigations, forestry, mineralogy, climatology, archaeology, agriculture, oil exploration, millitary intelligence etc.

(i) Revision of Existing Topo Sheets – The rapid revision and updating of existing toposheet can be carried with the help of aerial photography and satellite images.

(ii) Alignment of Highways and Railways – The location of most economical alternative site for highway and railway can will be carried out by making use of aerial photographs of the area.

(iii) Location of Dam Site – For gravity dam, it is necessary to have very good foundation in the form of hard strata of Rocks. Geological investigation of the existing, rock and around the dam site can be carried out by aerial photograph or satellite imagery. Geological features such as fault, folds, dykes can be determined by remote sensing technique.

(iv) Tunneling – A tunnel should not be aligned and excavated along the fractured stone or faults in the rocks. Remote sensing helps in furnishing all such information and thus insures the safety of the tunnel during its construction stage.

(v) Silting of Storage Reservoirs, Harbours etc. – Silting of harbours leads to reduction in the navigational depth and thus renders it useless. Similarly silting of storage reservoirs reduces its capacity. Remote sensing technique by using satellite imagery gives idea about the silting of reservoir qualitatively and to some extent quantitatively.

(vi) Location of Percolation Tank – The exact location of percolation tank can be determined keeping in view that the site required for location of percolation tank, should be on permeable foundations the percolation of water through such tanks joints the open wells on the downstream side which can be utilized for irrigation purpose.

(vii) Seepage Classes in Canal – By monitoring the soil moisture in and around the canal system, it has been possible to identify the seepage of water that taken place through such canals.

Other than these, there are various applications of remote sensing as follows –

(i) Environmental Applications – Remote sensing gives more environmental information. The remote sensing satellites are used for weather forecasting. It is useful to know ocean conditions. It detects the pollution in forms of oil spills and thermal plumes. Scientists are using remote sensors to know about the ozone layer depletion and global warming.

(ii) Mineral Exploration – Remote sensing techniques helps for detailed exploration of non-renewable resources like minerals etc. It helps in detecting hydro thermally altered rocks associated with ore deposits. It provides basic geological data.

(iii) Land Use and Land Cover Analysis – With the development of cities, it is visible that agricultural land is being used for urban purposes and forests are being cut-off to provide land for cultivation. These changes are harmful to human interests and may prove disastrous. To prevent these damages to the environment, it is necessary to plan and regulate these changes. For that remote sensing techniques are widely used. These techniques provides us images of large areas very accurately and rapidly as well as it provides perspective images of the field. By using these techniques, interpretation is faster and cheaper.

(iv) Natural Hazards – Earthquakes, land slides, volcanic eruptions and floods are various natural hazards which causes the various losses. With the help of remote sensing we may minimize the damages by identifying the risk prone areas, by predictions of earth movements, warnings to earth quakes etc.

(v) Archaeology – Remote sensing helps in identifying the prehistoric land and buildings of archaeological patterns. Many of the buildings, roads, towns, the characteristics of these underlying old objects those are of archaeological importance are recognize with the help of remote sensors. So as remote sensing is an important tool for structures of archaeological pattern.

Q.26. Explain the importance of remote sensing in civil engineering.* *(R.G.P.V., Dec. 2016)

Ans. Refer Q.25.

Q.27. What are the advantages of remote sensing over other methods of surveying ?* *(R.G.P.V., June 2002)

Ans. There are various advantages of remote sensing over other methods of surveying –

(i) It provides information about an object, situated at a long distance.
(ii) It is cheaper than other methods of surveying.
(iii) It covers more area than other methods of surveying.
(iv) It provides much accuracy.
(v) It helps in identifying the risk prone areas.

■■

UNIT 4

FORCES AND EQUILIBRIUM

GRAPHICAL AND ANALYTICAL TREATMENT OF CONCURRENT AND NON-CONCURRENT COPLANAR FORCES

Q.1. What is engineering mechanics ?

Or

Define engineering mechanics.

Ans. Engineering mechanics or applied mechanics is that branch of applied science which deals with the study of sets (or systems) of forces; study of effects produced by forces acting on rigid bodies and particles and study of geometry of motion of rigid bodies and particles.

There are four basic concepts involved in engineering mechanics, viz. space, time, mass and force. Out of these four space, mass and time are considered in absolute terms and they do not depend on one another while the concept of force is derived from space, mass and time.

Q.2. Classify the engineering mechanics and briefly explain them.

Ans. The subject of engineering mechanics may be divided into following two main branches –

(*i*) ***Statics*** – Statics, is that branch of engineering mechanics, which deals with the study of system of forces and effects produced by these forces on rigid bodies, which are at rest and remains at rest. Subject of statics include topics such as resultant of force system, location of centroid, e.g. analysis of equilibrium, frictional forces and principle of virtual work.

(*ii*) ***Dynamics*** – Dynamics, is that branch of engineering mechanics, which deals with the study of system of forces and motion produced by these forces by acting on rigid bodies. Dynamics may be further sub-divided into following two branches –

(a) Kinematics – Kinematics is the study of the motion of particles and rigid bodies without considering the effect of force and mass. Kinematics relates such quantities as distance, displacement, velocity, acceleration, time of motion, equation of path of motion, etc.

(b) Kinetics – Kinetics is the study of relations between the mass of the body, forces acting on it and the resultant motion. Kinetics relates such quantities as mass, force, velocity, acceleration, work, energy, power, momentum, impulse, moment of inertia, etc.

Q.3. Define the following terms –
(i) Body (ii) Rigid body (iii) Particle.

Ans. (i) Body – A body is a portion of matter which occupies a finite space. A body is made up of atoms and molecules arranged in a complex but continuous manner. Such an arrangement of matter is called as a continuum. A body may be rigid or non-rigid (deformable).

(ii) Rigid Body – A body which does not change its shape or size when subjected to external forces, is defined as the rigid body. In actual practice, there is no perfect rigid body, all bodies undergo deformation when subjected to external forces.

However, if these deformations are negligible as compared to the size of the body, it may be assumed as a rigid body. For example, beams, trusses, frames and other structures which have negligible deformation can be considered as rigid bodies.

(iii) Particle – A particle may be defined as a portion of matter having smallest size or is dimensionless. A body whose dimensions are negligible as compared to distance travelled by it during the motion may also be treated as a particle. Mathematically, a particle may be considered as a body in which all materials are concentrated at a point. For example, sun, planets and stars can also be considered as particles because their dimensions are very small as compared to distance travelled by them.

Q.4. Define force and give its units.

Ans. Force may be defined as, "an external agent which produces or tends to produce, destroys or tends to destroy motion."

In other words, a force is a pull or push, which when acts on a body changes or tends to change, the state of rest or of uniform motion of the body.

In SI units, force is measured in Newtons (N) and in MKS units it is easured in kilogram force (kgf), where

$$1 \text{ kgf} = 9.81 \text{ N}$$

A force is a vector quantity, thus along with its magnitude its direction nd point of application also has to be specified.

Q.5. What are the various types of forces ? ***(R.G.P.V., Dec. 2014)***

Or

Define various types of forces with the help of sketches.
(R.G.P.V., Dec. 2012)

Or

Write short note on – System of forces. ***(R.G.P.V., Dec. 2001)***

Ans. When a number of forces act on a body, or group of bodies, they form a system of forces or force system. Depending upon the orientation of forces acting on a body the system of forces may be classified as –

(i) Coplanar Force System – When lines of action of all the forces of force system lies in the same plane, the force system is called coplanar force system.

(ii) Non-coplanar Force System – When lines of action of the forces of force system do not lie in the same plane, the force system is called as non-coplanar force system.

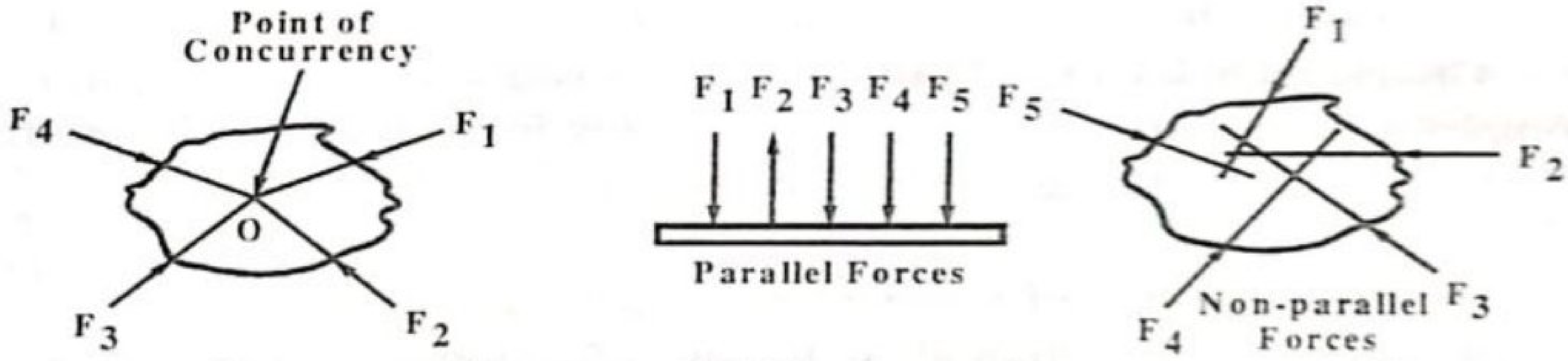
(iii) Collinear Forces – The forces, whose lines of action lie on same line are known as collinear forces.

(iv) Parallel Forces – The forces, whose lines of action are parallel to each other are known as parallel forces.

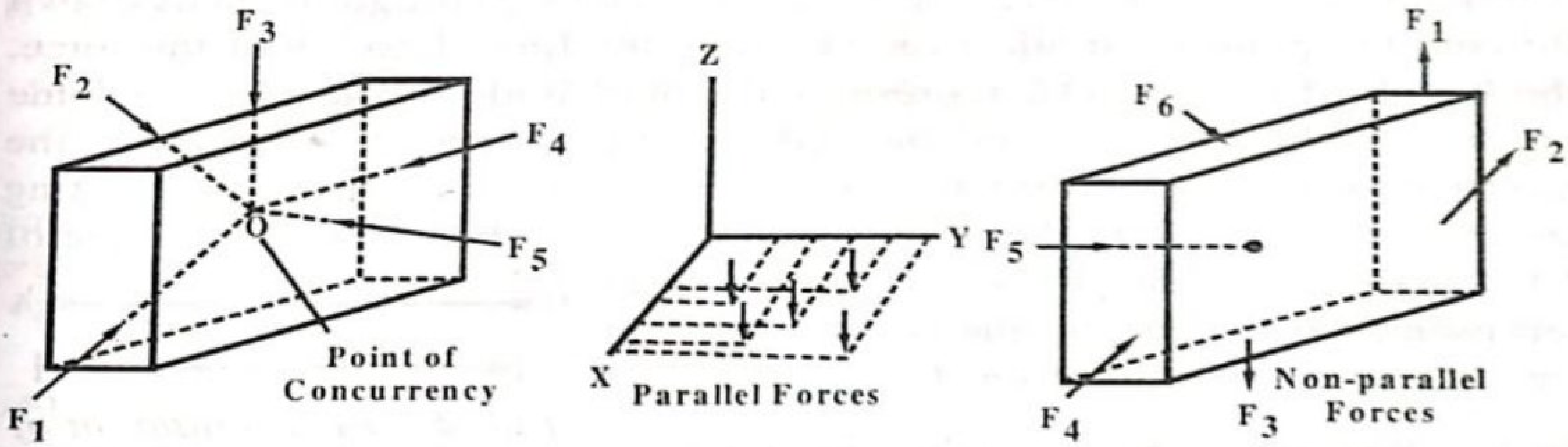
(v) Concurrent Forces – The forces, which meet at one point are known as concurrent forces. Concurrent forces may or may not be collinear.

(vi) Non-concurrent Forces – The forces, which do not meet at one point are known as non-concurrent forces.

Both coplanar and non-coplanar forces may be concurrent, non-concurrent, parallel and non-parallel as shown in fig. 4.1.



(a) Coplanar, Concurrent Forces *(b) Coplanar, Non-concurrent Forces*



(c) Non-coplanar, Concurrent Forces *(d) Non-coplanar, Non-concurrent Forces*

Fig. 4.1 System of Forces

Q.6. Define –
(i) Coplanar forces (ii) Concurrent forces.
(R.G.P.V., Dec. 2015)

Or

What do you understand by coplanar and concurrent forces ?
(R.G.P.V., June 2016)

Ans. Refer Q.5.

Q.7. What is the difference between collinear and concurrent forces ?
(R.G.P.V., June 2015)

Ans. Refer Q.5.

Q.8. What effects of force can produce on a body ? Also give characteristics of a force.

Ans. **Effects of Force** – A force acting on a body may produce one or more of the following effects –

(i) It may change the motion of the body, i.e. if the body is at rest force may set the motion in it, and if the body is already in motion the force may accelerate or retard its motion.

(ii) It may retard the forces already acting on a body, thus bringing it to rest or in equilibrium.

(iii) It may produce the internal stresses in a body on which it acts.

Characteristics of a Force – A force is a vector quantity, in order to completely represent a force we have to know following four characteristics –

(i) Magnitude of the force vector
(ii) Its point of application
(iii) The line of action along which it acts
(iv) The direction along the line of action.

Thus, we can completely represent a force by a straight line OA drawn through the point of application, O, along the line of action of the force, the length of the line OA represents the magnitude of the force to some arbitrarily chosen scale and the order of the letters O, A specifies the direction of force. The direction of action of force is indicated by putting an arrow on the line in the direction of the force. For example, a force of 10 N acting at point O towards right can be represented by a straight line OA as shown in fig. 4.2, directed from point O towards right on a conveniently chosen scale. The line $\overrightarrow{OA}$ represents a force of 10 N in magnitude, direction and sense.

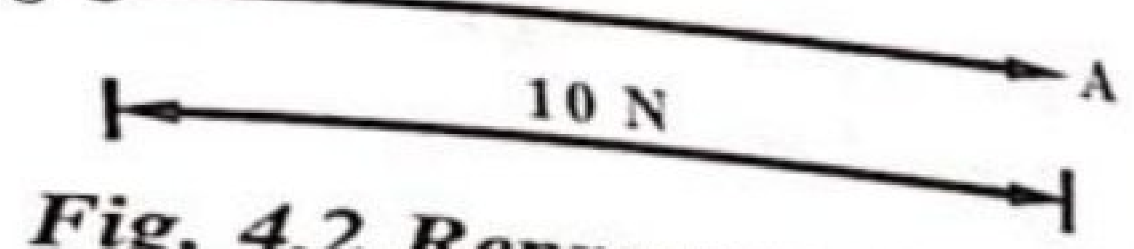


Fig. 4.2 Representation of a Force

Q.9. Describe method of resolution of forces. ***(R.G.P.V., July 2008)***

Ans. The process of splitting up a force along two mutually perpendicular directions generally X and Y axes, without changing its effect on the body is called resolution of a force.

Consider a force F acting at an angle θ with the X-axis, as shown in fig. 4.3.

Now the component of force F along X-axis will be

$$F_x = F \cos\theta$$

and along Y-axis, it will be

$$F_y = F \sin\theta$$

Similarly, a number of forces can be resolved.

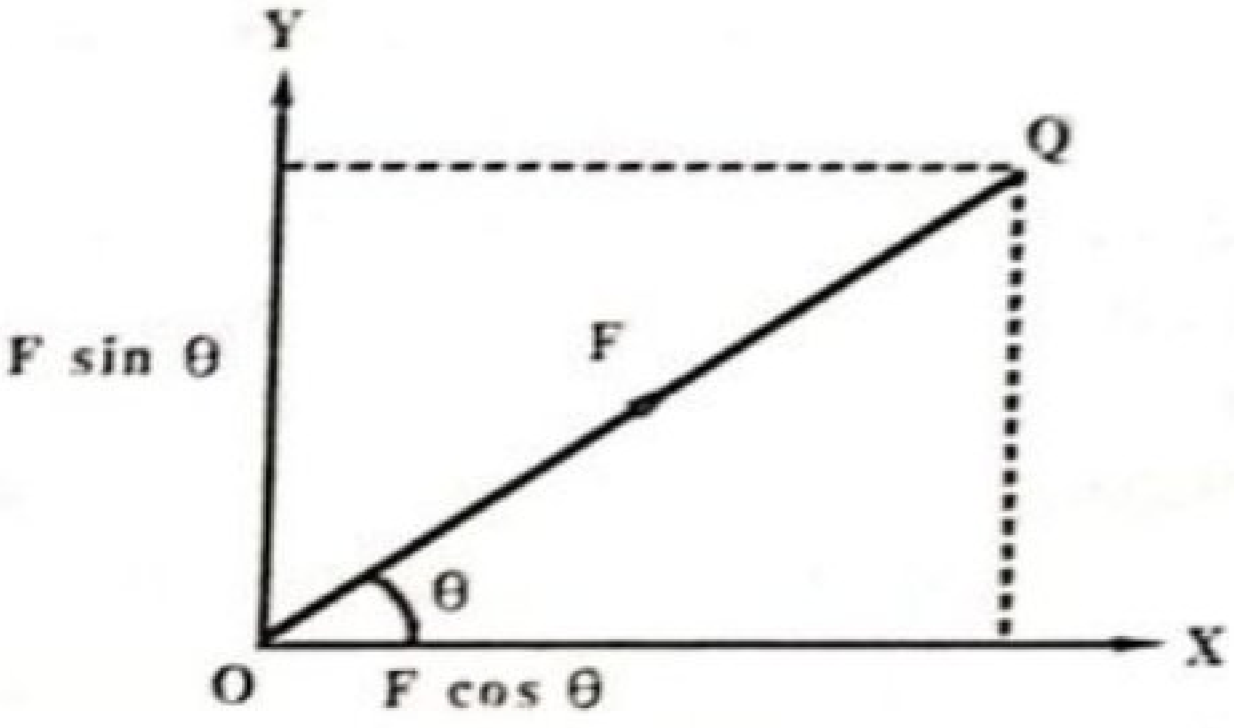


Fig. 4.3

If line of action of force F_x goes towards right, F_x is taken as positive, otherwise it is taken as negative. Similarly, if line of action of force component F_y goes upwards, F_y is taken as +ve, otherwise it is taken as –ve.

Component F cos θ is always connected with the angle θ, if angle θ is measured with Y-axis, then

$$F_y = F \cos\theta$$

Q.10. What do you understand by composition of forces ?

Ans. Composition is a process of adding two or more forces. If a number of forces F_1, F_2, F_3....etc. are acting simultaneously on a particle, then it is possible to find out a single force which would produce the same effect as was produced by all the given forces. This single force is called as the ***resultant force*** and represented by R. The given forces, F_1, F_2, F_3 .... etc. are called component forces.

The method of finding out the resultant force of a number of given forces is called ***composition of forces*** or ***compounding of forces.***

Q.11. Differentiate between resultant and equilibrant.

(R.G.P.V., Dec. 2002)

Ans. If a number of forces are acting simultaneously on a particle, it is possible to find out a single force which could replace them, i.e. which would produce the same effect as produced by all the given forces. This single force is called ***resultant force.***

This resultant force, causes the body to move. Now, if another force, which is equal in magnitude of the resultant but opposite in direction is applied to the body, the body comes to rest. The force, which brings the set of forces in equilibrium is called an ***equilibrant.*** This equilibrant force is equal to the resultant force in magnitude, but opposite in nature.

Q.12. Name various methods for determining resultant of two concurrent forces. Explain any one of them.

Ans. Resultant of two concurrent forces can be determined graphically by following two methods –

(i) Parallelogram law of forces (ii) Triangle law of forces.

Parallelogram Law of Forces – It states, "if two forces acting simultaneously on a particle, be represented in magnitude and direction by the two adjacent sides of a parallelogram, then the resultant force can be represented in magnitude and direction by the diagonal of parallelogram which passes through the point of intersection of two sides".

Graphically it can be explained as –

(i) Choose an arbitrary scale to represent forces F_1 and F_2.

(ii) From point O, draw a vector Oa on chosen scale to represent force F_1 as shown in fig. 4.4.

(iii) Now from point O, draw another vector Ob to represent force F_2 at an angle θ (refer fig. 4.4)

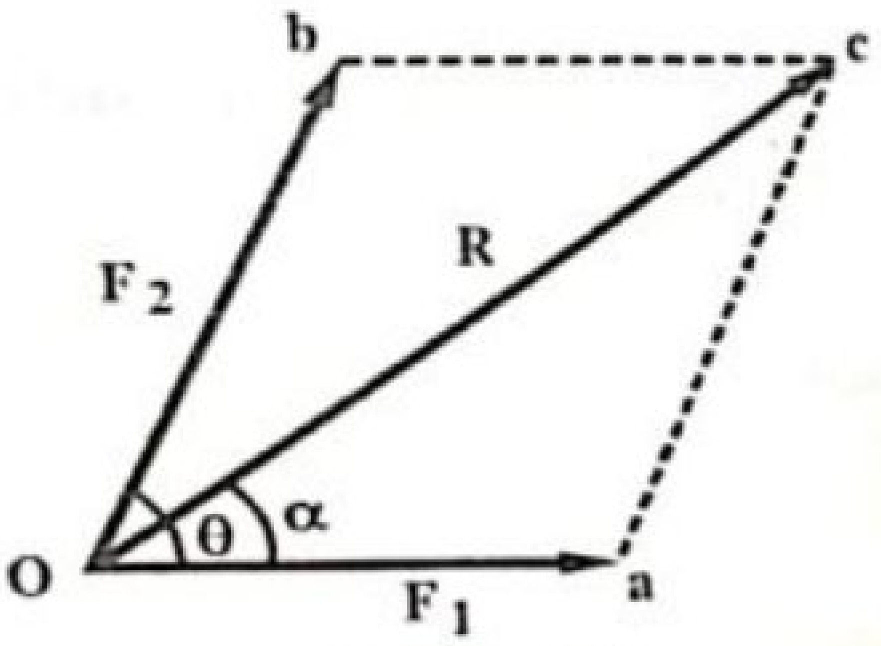


Fig. 4.4

(iv) Complete the parallelogram by drawing lines ac ‖ Ob and bc ‖ Oa.

(v) Measure the length Oc. Then resultant will be equal to

R = length Oc × chosen scale

(vi) Also measure the angle α made by Oc with Oa, it will give the direction of resultant.

Q.13. State and prove parallelogram law of forces.

Ans. For statement of parallelogram law of forces, refer Q.12.

Mathematical relationship between forces F_1, F_2 and their resultant R can be derived as follows –

Consider parallelogram OACB in which OA and OB represent the forces F_1 and F_2 acting at a point O. Then the diagonal OC will represent the resultant force R.

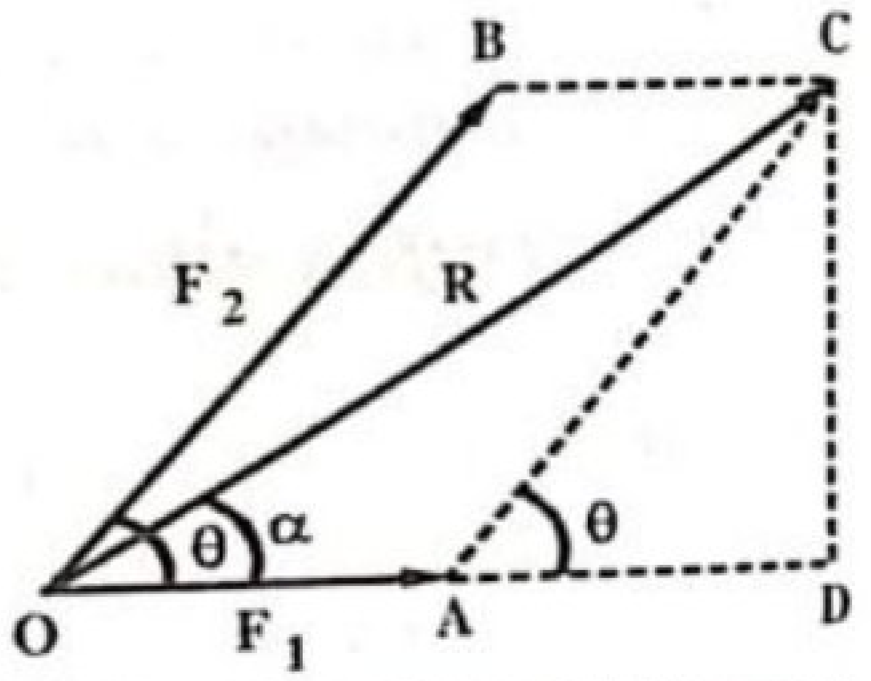


Fig. 4.5 Parallelogram Law of Forces

In Δ OCD, (fig. 4.5)

$$(OC)^2 = (OA + AD)^2 + (CD)^2$$
$$= (OA)^2 + (AD)^2 + 2(OA)(AD) + (CD)^2$$

But from Δ CAD

$$(AC)^2 = (AD)^2 + (CD)^2$$

$$\text{or} \qquad (CD)^2 = (AC)^2 - (AD)^2$$

$$\therefore \qquad (OC)^2 = (OA)^2 + (AD)^2 + 2(OA)\,(AD) + (AC)^2 - (AD)^2$$

$$(OC)^2 = (OA)^2 + 2(OA)\,(AD) + (AC)^2$$

$$(OC)^2 = (OA)^2 + 2(OA)\,(AD) + (OB)^2 \qquad (\because AC = OB)$$

Substituting values from figure

$$R^2 = F_1^2 + 2F_1F_2\cos\theta + F_2^2$$

$$\therefore \qquad R = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$$

and angle between the resultant force R and force F_1 will be given by

$$\tan\alpha = \frac{CD}{OA + AD} = \frac{F_2\sin\theta}{F_1 + F_2\cos\theta}$$

Now consider the following special cases –

Case-I – When forces act at right angle, i.e. $\theta = 90°$ or $\cos\theta = 0$

$$\therefore \qquad R = \sqrt{F_1^2 + F_2^2} \quad \text{and} \quad \tan\alpha = \frac{F_2}{F_1}$$

Case-II – When forces are collinear and act in same direction, i.e. $\theta = 0°$ or $\cos\theta = 1$.

$$\therefore \qquad R = F_1 + F_2$$

$$\text{and} \qquad \tan\alpha = 0 \text{ or } \alpha = 0°$$

Case-III – When forces are collinear but act in opposite direction, i.e. $\theta = 180°$ or $\cos\theta = -1$.

$$\therefore \qquad R = F_1 - F_2$$

$$\text{and} \qquad \tan\alpha = 0 \text{ or } \alpha = 0°$$

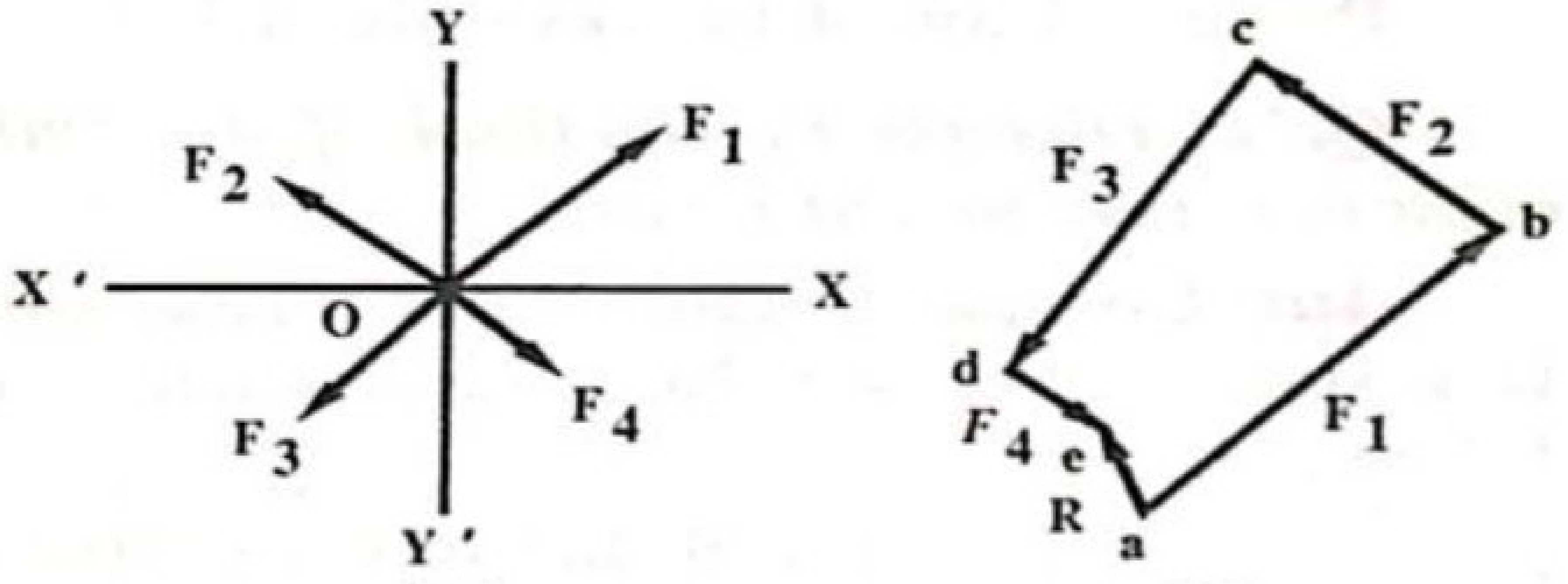
In this case, resultant force acts in the direction of the greater force.

Q.14. State and explain the law of polygon of forces.

(R.G.P.V., June 2015)

Ans. Polygon law of forces is the graphical method of determining the resultant of more than two concurrent forces.

It states, if a number of concurrent forces acting simultaneously on a body, be represented in magnitude and direction by the sides of the polygon taken in order, then their resultant will be represented by the closing side of the polygon in magnitude and direction taken in opposite order.



(a) *(b)*

Fig. 4.6 Polygon Law of Forces

If four forces F_1, F_2, F_3 and F_4 acting on a particle as shown in fig. 4.6 (a) are represented in magnitude and direction by the sides ab, bc, cd and de of a polygon respectively, then their resultant will be represented by the closing side ea but in opposite direction as shown in fig. 4.6 (b).

Q.15. State and explain the triangle law and polygon law of forces.
(R.G.P.V., Dec. 2012)

Ans. **Triangle Law of Forces** – Triangle law of forces is the graphical method of finding resultant of two concurrent forces.

It states, "if two concurrent forces acting simultaneously at a point be represented in magnitude and direction by the sides of a triangle taken in the same order, their resultant is represented by the third side (closing side) in magnitude and direction taken in opposite order."

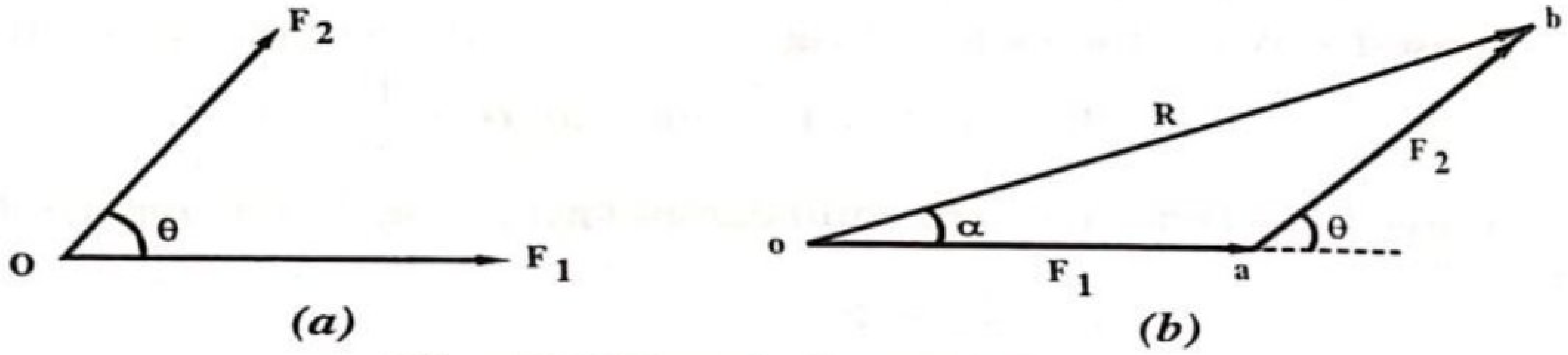


Fig. 4.7 Triangle Law of Forces

If two forces F_1 and F_2 are acting at an angle θ as shown in fig. 4.7 (a), their resultant by triangle law of forces can be found as follows –

(i) Draw a line oa parallel and equal to F_1 on some convenient scale.

(ii) From a, draw a vector ab at an angle θ to the horizontal and length equal to the magnitude of force F_2 on chosen scale.

(iii) Close the triangle by joining line ob. Vector ob represents the magnitude and direction of resultant R.

Magnitude of resultant will be given by length ob × chosen length and angle α gives the direction of resultant.

Polygon Law of Forces – Refer Q.14.

Q.16. Discuss the method of determining resultant of a system of coplanar, concurrent forces.

Ans. Consider a number of coplanar forces F_1, F_2, F_3... acting at a point O as shown in fig. 4.8. Now the resultant of this force system can be found in following steps –

(i) Resolve all the forces horizontally, i.e. along X-axis and find their algebraic sum. Mathematically,

$$\Sigma H = F_1 \cos \theta_1 + F_2 \cos \theta_2 + F_3 \cos \theta_3 + ...$$

(ii) Resolve all the forces vertically, i.e. along Y-axis and find their algebraic sum. Mathematically,

$$\Sigma V = F_1 \sin \theta_1 + F_2 \sin \theta_2 + F_3 \sin \theta_3 + \dots$$

(iii) Now resultant of given force system can be found by using the principle of resolution, which states, "the algebraic sum of the resolved parts of a number of forces in a given direction is equal to the resolved part of their resultant in the same direction." Thus, resultant force

$$R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2}$$

(iv) The direction of resultant force with X-axis is given by,

$$\tan \theta = \frac{\Sigma V}{\Sigma H}$$

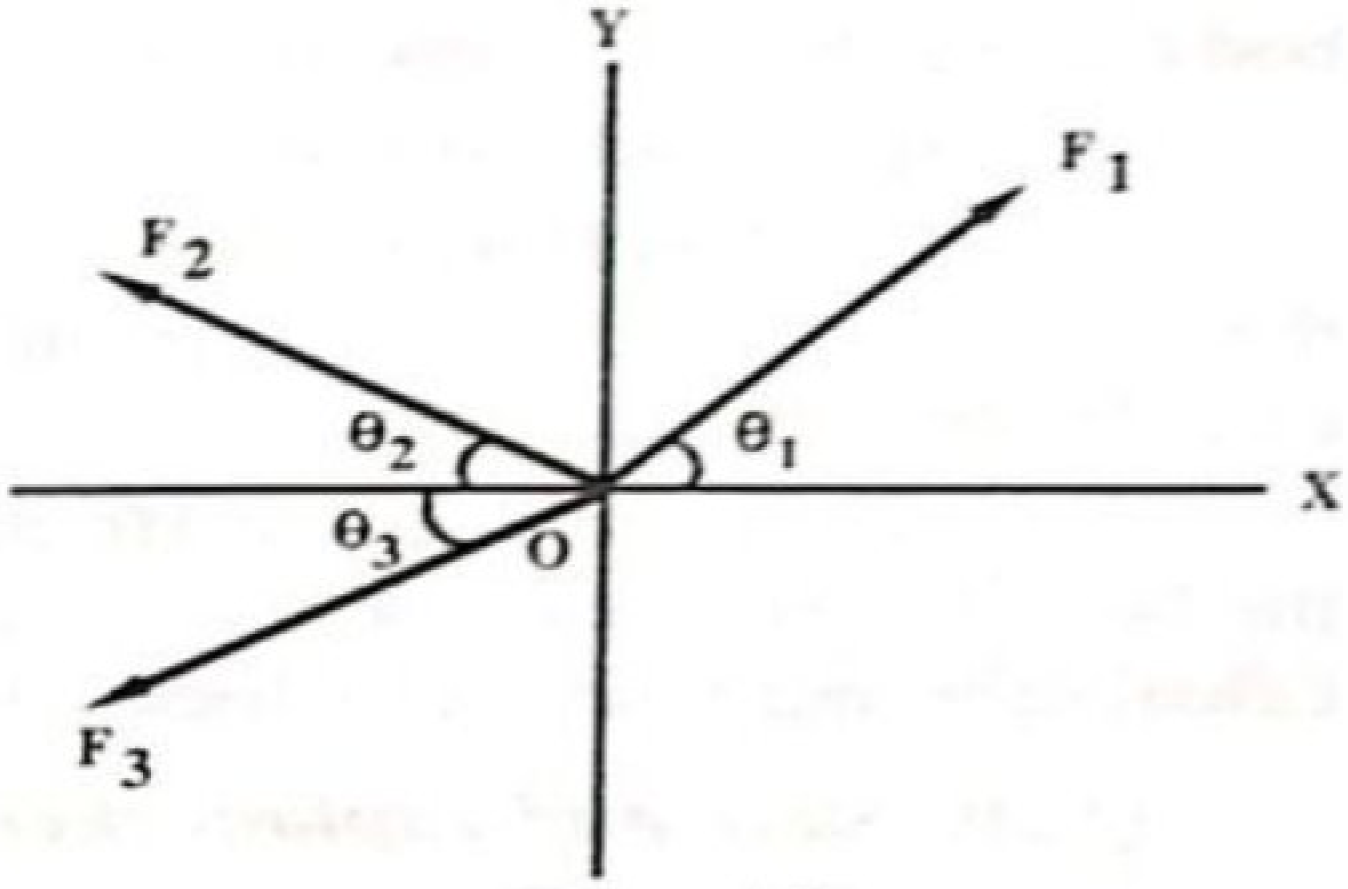


Fig. 4.8

Q.17. What do you mean by moment of a force ?

Ans. When we apply a force on the body, it has the tendency to turn the body about some point. This tendency of a force to turn the body about a point is called as the moment of the force about that point, and it is measured by the product of the force and the perpendicular distance of its line of action from the point.

Consider a force F is acting on a body as shown in fig. 4.9, and moment of this force is required to find about point O.

Let r = Perpendicular distance from point O to the line of action of force F.

The moment of the force about O will be given by,

$$M = F \times r$$

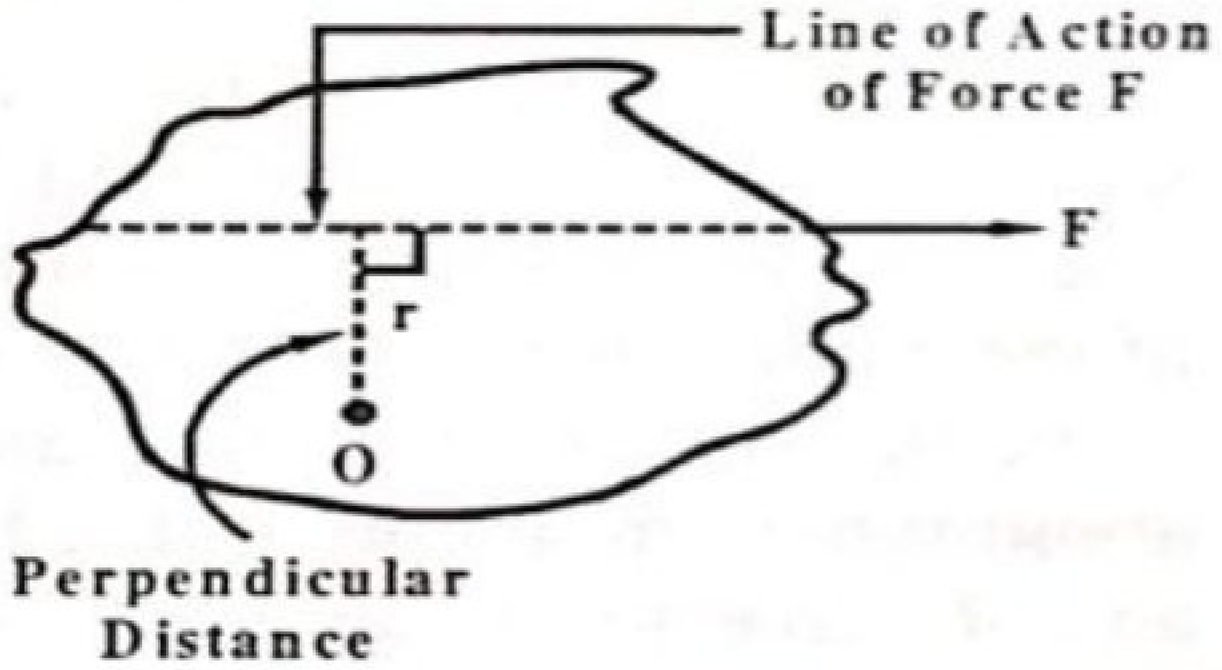


Fig. 4.9 Moment of a Force

In S.I. units moment of a force is expressed in N-m.

A moment has both magnitude and direction and adds according to the parallelogram law of addition. Hence, it is a vector quantity.

Q.18. Give reason why moment of a force is considered only for non-concurrent forces.

Ans. Moment of a force can be defined as the tendency of the force to turn the body about a point. In case of concurrent, coplanar forces, body can be considered as a particle and turning effect of forces on the body is not considered. But, when the size of the body is large and forces acting are non-concurrent, the body cannot be considered as particle, and we also have to consider the turning effect of the forces.

Q.19. What do you mean by clockwise and anticlockwise moments ?

Ans. Depending upon the direction in which moment tends to rotate the body, it can be of following two types –

(i) Clockwise moment (ii) Anticlockwise moment.

(i) Clockwise Moment – When moment of a force tries to rotate the body in clockwise direction, it is termed as clockwise moment. For calculation purposes, clockwise moment is taken as –ve.

(ii) Anticlockwise Moment – When moment of a force tries to rotate the body in anticlockwise directon, it is termed as anticlockwise moment. For calculation purposes, anticlockwise moment is taken as +ve.

Q.20. State and explain theorem of Varignon. ***(R.G.P.V., June 2014)***

Or

State and prove Varignon's theorem. ***(R.G.P.V., Jan./Feb. 2008, Dec. 2008, Sept. 2009, Feb. 2010, June 2010, 2012)***

Or

Explain Varignon's theorem. ***(R.G.P.V., June 2007, 2011, 2013)***

Ans. Varignon's theorem states, "if a number of coplanar forces are acting on a body, then algebraic sum of the moments of all the forces about any point in their plane is equal to the moment of their resultant force about the same point."

Proof – Consider two concurrent forces F_1 and F_2 acting at point O, represented in magnitude and direction by OA and OB, as shown in fig. 4.10. Their resultant is represented in magnitude and direction by OC, the diagonal of the parallelogram OACB. Let O' be the any point in the plane about which moments of F_1, F_2 and R have to be determined. From point O', perpendiculars are drawn on OA, OB and OC.

Now line OO' is joined and produce to X. From points C, A and B perpendiculars are drawn which meets line OX at points D, E and F respectively. Line CD is joined and perpendiculars are drawn on it from point A and B, which meets CD at G and H respectively.

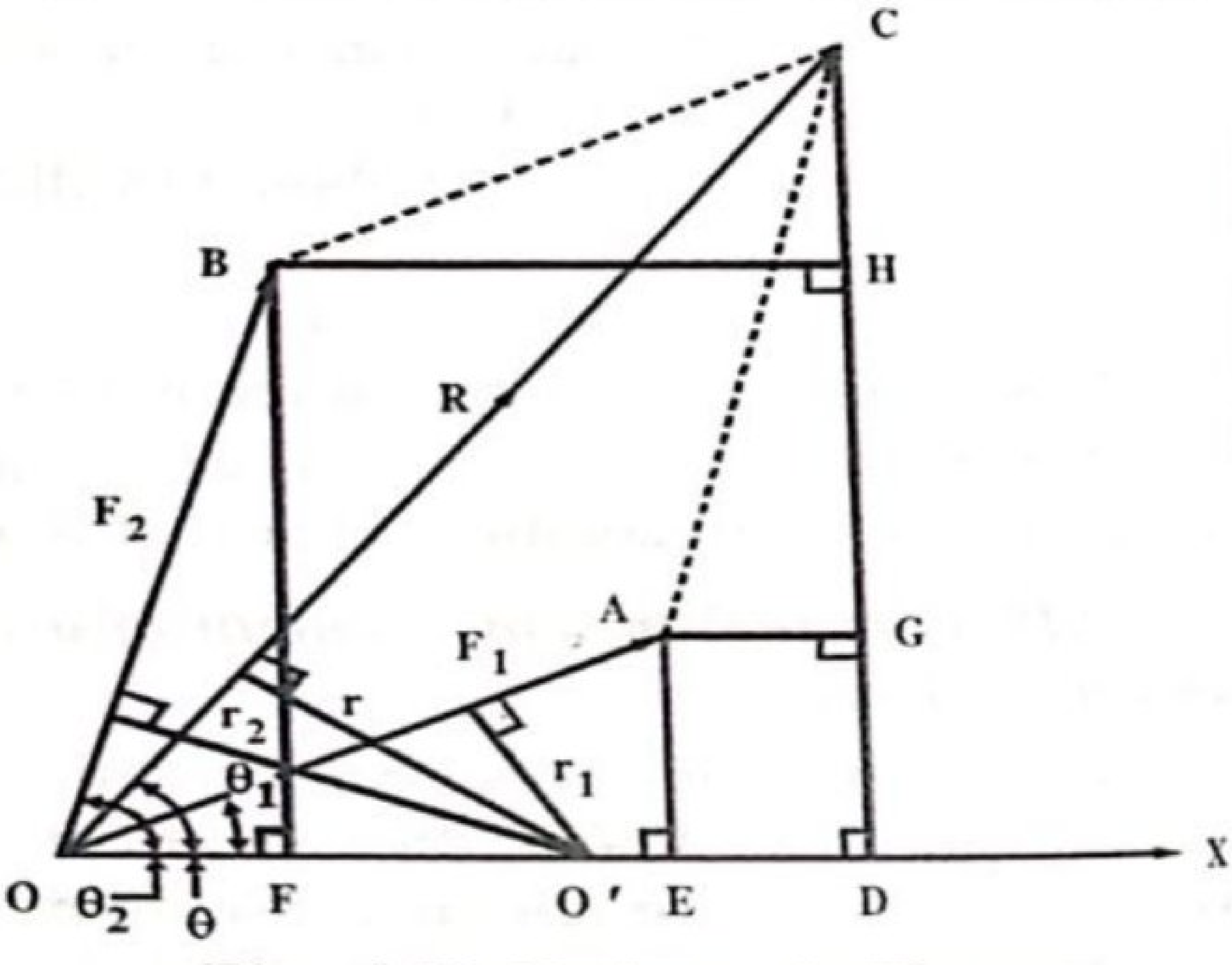


Fig. 4.10 Varignon's Theorem

Let,
r_1 = Perpendicular distance between F_1 and O'
r_2 = Perpendicular distance between F_2 and O'
r = Perpendicular distance between R and O'
θ_1 = Angle made by F_1 with OX
θ_2 = Angle made by F_2 with OX
θ = Angle made by R with OX

Now from fig. 4.10, we have OA = BC and OA ∥ BC, hence projection of OA and BC on same vertical line CD will be equal, i.e.

$$GD = CH$$

Similarly, OB = AC and also OB ∥ AC, therefore their projection on same horizontal line OX will be equal, i.e.

$$OF = ED$$

Now resolving the forces in X and Y components, we have from figure

$$F_1 \cos\theta_1 = OE$$
$$F_1 \sin\theta_1 = AE = GD = CH$$
$$F_2 \cos\theta_2 = OF = ED$$
$$F_2 \sin\theta_2 = BF = HD$$
$$R \cos\theta = OD$$
$$R \sin\theta = CD$$

Let length OO' = x, then

$$r_1 = x \sin\theta_1,\ \ r_2 = x \sin\theta_2, \text{ and } r = x \sin\theta.$$

Now, moment of resultant R about O'

$$= R \times (\text{Perpendicular distance between O' and R})$$
$$= R \times r = R \times x \sin\theta$$
$$= (R \sin\theta)x = CDx \qquad (\because R \sin\theta = CD)$$
$$= (CH + HD)x$$
$$= (F_1 \sin\theta_1 + F_2 \sin\theta_2)x \ (\because CH = F_1 \sin\theta_1 \text{ and } HD = F_2 \sin\theta_2)$$
$$= F_1.x \sin\theta_1 + F_2.x \sin\theta_2$$
$$= F_1.r_1 + F_2.r_2$$
$$= \text{Moment of } F_1 \text{ about O'} + \text{Moment of } F_2 \text{ about O'}$$

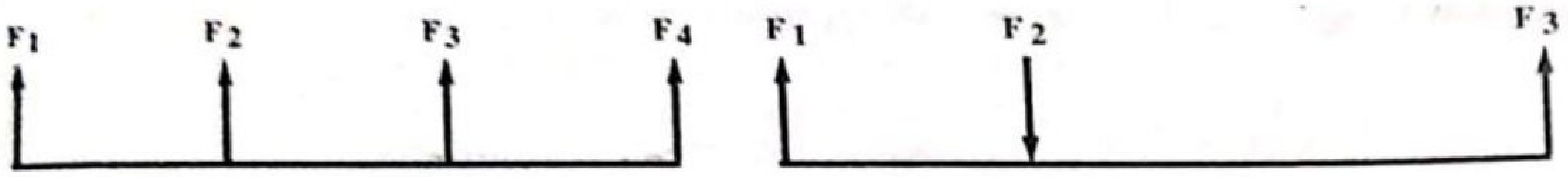
This proves the Varignon's theorem. This theorem can be applied to any coplanar force system, whether concurrent, non-concurrent or parallel force system.

Q.21. What are parallel forces ? How their resultant can be determined?

Ans. Forces, whose lines of action are parallel to each other are known as parallel forces. Parallel forces can be of two types –

(i) Like parallel (ii) Unlike parallel.

The parallel forces acting in the same direction as shown in fig. 4.11 (a) are known as ***like parallel forces.*** The parallel forces acting in opposite directions as shown in fig. 4.11 (b), are known as ***unlike parallel forces.***



(a) Like parallel Forces *(b) Unlike Parallel Forces*

Fig. 4.11

Resultant of parallel forces can be found by algebraic addition of all forces, while its location can be found by Varignon's theorem.

For fig. 4.11 (a), resultant, $R = F_1 + F_2 + F_3 + F_4$
and for fig. 4.11 (b), resultant, $R = F_1 - F_2 + F_3$

Q.22. Explain the method of determining location of resultant of two like parallel forces.

Ans. Consider a rigid body as shown in fig. 4.12 on which two like parallel forces F_1 and F_2 are acting. The location of point at which their resultant is acting can be found out by using Varignon's theorem.

According to Varignon's theorem, the algebraic sum of moments of forces F_1 and F_2 about any point should be equal to the moment of the resultant (R) about the same point. Let us select a point O along the line AB.

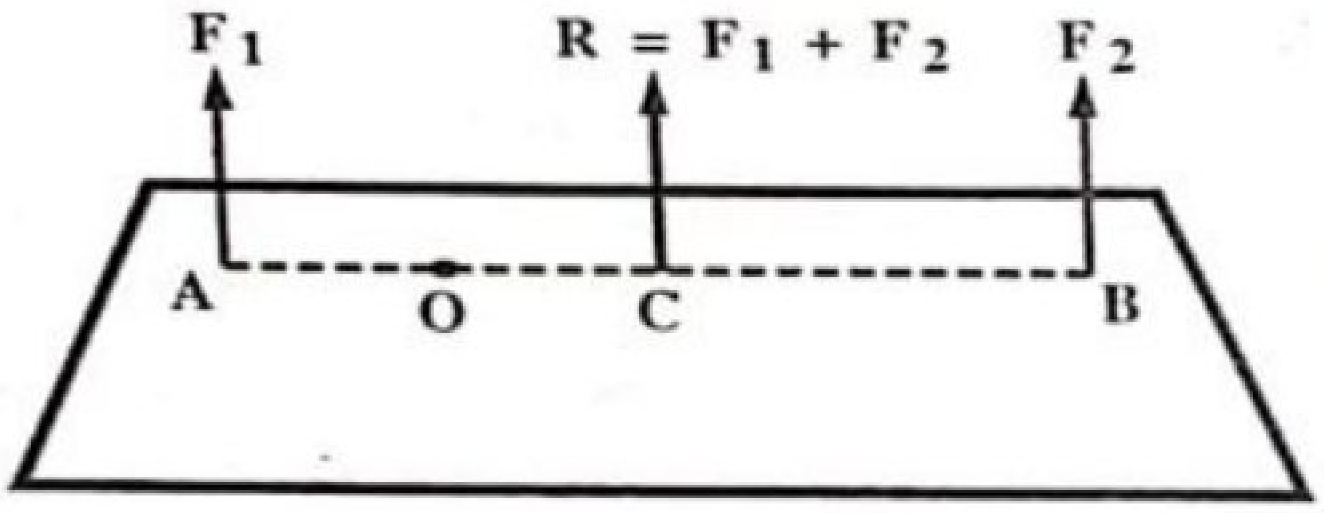


Fig. 4.12

Moment of force F_1 about O

$= F_1 \times AO$ (clockwise)

Moment of force F_2 about O

$= F_2 \times BO$ (anticlockwise)

and moment of resultant R about O

$= R \times CO$ (anticlockwise)

Now according to the Varignon's theorem,

$$-F_1 \times AO + F_2 \times BO = R \times CO$$

$$-F_1 \times AO + F_2 \times BO = (F_1 + F_2) \times CO \qquad (\because R = F_1 + F_2)$$

or

$$F_1(AO + CO) = F_2(BO - CO)$$

$$F_1 \times AC = F_2 \times BC$$

or

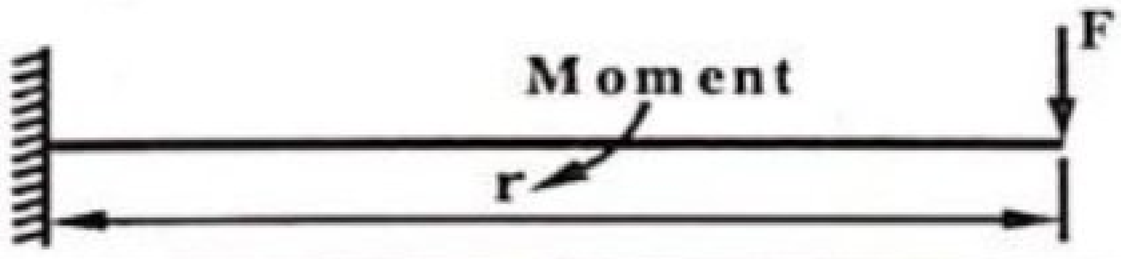
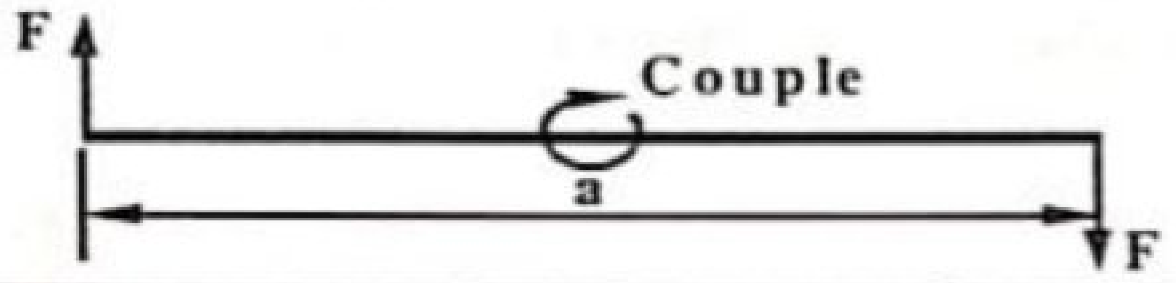
$$\frac{F_1}{F_2} = \frac{BC}{AC}$$

Thus, the resultant R will act at point C, parallel to the lines of action of the given forces F_1 and F_2, in such a way that point C divides the distance AB in the ratio inversely proportional to the ratio of forces F_1 and F_2.

Q.23. What is couple ? Differentiate between moment and couple.
(R.G.P.V., June 2013)

Ans. Two equal, unlike and parallel forces whose lines of action are not the same, form a couple. Resultant of such forces is zero but there acts the moment of forces. Thus, a couple tends to rotate the body on which it acts. A couple may be clockwise or anticlockwise depending upon the direction in which it tends to rotate the body. The perpendicular distance between the lines of action of the parallel forces is known as arm of the couple.

Differences between Moment and Couple – Differences between moment and couple are given below –

S.No.	*Moment*	*Couple*
(i)	Moment is produced due to only one force, and it is measured by the product of the force and the perpendicular distance of its line of action from a fixed or hinged point.	Couple is produced by two equal, unlike and parallel forces whose lines of action are not the same.
(ii)	Moment tends to turn the body about the fixed point either in clockwise or anticlockwise direction	Couple tends to rotate the body on which it acts either in clockwise or anticlockwise direction.
(iii)	Moment produces bending moment on a body.	Couple produces twisting moment on a body.
(iv)	Moment is represented as shown below – 	Couple is represented as shown below – 

Q.24. Write short note on – Couple. ***(R.G.P.V., Dec. 2016)***

Ans. For definition of couple, refer Q.23.

Characteristics of Couple – A couple has the following characteristics–

(i) The algebraic sum of forces constituting the couple, is zero.

(ii) The algebraic sum of the moments of the forces, constituting the couple, about any point in their plane is constant and equal to the moment of the couple.

(iii) A couple cannot be balanced by a single force. But it can only be balanced by a couple of opposite sense.

(iv) Any number of coplanar couples are together equivalent to a single couple whose moment is equal to the algebraic sum of the moments of the couples.

Q.25. Define equivalent force system.

Ans. For a given coplanar force system, an equivalent force system is a combination of a single force passing through a given point and a moment about that point, which produces the same effect as the complete force system altogether. The force in the equivalent force system is the resultant of all forces acting on the body, and the moment is the sum of all the moments about that point. Hence an equivalent force system consists of –

(i) A single force R passing through the given point (say O), and

(ii) A single moment M_R about point O.

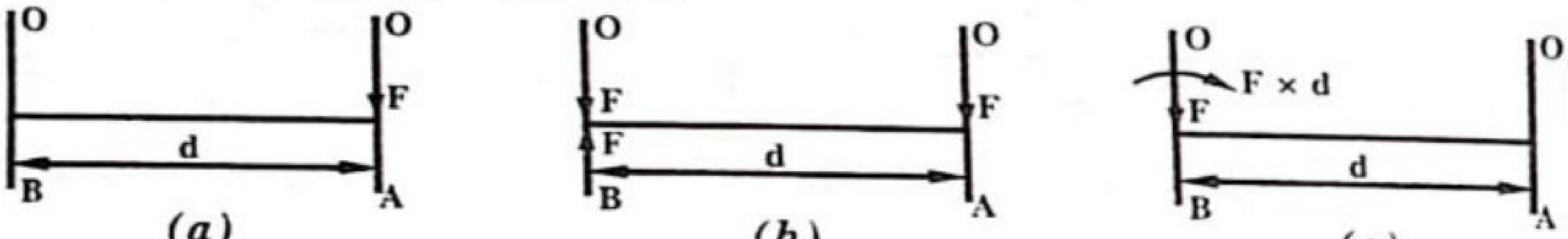
Q.26. Show how a force acting on a body can be replaced by an equivalent force-couple system. ***(R.G.P.V., June 2014)***

Ans. A force F acting on a body can be translated to an equivalent force F acting at an arbitrary point O parallel to the given force, together with a couple whose moment is equal to the product of F with the perpendicular distance of O from the given force.

Consider a force F acting along the line OA as shown in fig. 4.13 (a). We want to translate this force to a parallel line of action OB.

To achieve this, two equal and opposite forces F are applied along the line OB as shown in fig. 4.13 (b). Since two forces are equal, opposite and collinear, therefore they are in equilibrium.

Now the force F acting along OA and the equal and opposite force F acting along OB will constitute a couple, while the force acting downwards along OB is the same as if the force acting along OA is translated to OB. This situation is shown in fig. 4.13 (c).



(a) (b) (c)

Fig. 4.13

Q.27. What do you understand by moment of a couple ? Also define equivalent couple.

Ans. **Moment of a Couple** – The moment of a couple is the product of one of the forces forming the couple and the arm of the couple.

The algebraic sum of the moments of two forces forming a couple about any point in their plane is constant and equal to the moment of the couple. The moment of a couple is said to be positive when it is anticlockwise and negative when clockwise.

If each force of the couple be P and the perpendicular distance between their lines of action be p, then

Moment of the couple = Pp

Equivalent Couple – Equivalent couple may be defined as the single couple of any number of coplanar couples, whose moment is equal to the algebraic sum of the moments of the couples.

NUMERICAL PROBLEMS

Prob.1. The following forces act at a point –

(i) 25 N inclined 30° towards North from East

(ii) 20 N towards North

(iii) 35 N towards North-West

(iv) 45 N inclined 45° towards South from West.

Find the magnitude and direction of the resultant force.

(R.G.P.V., April 2009)

Sol. The system of given forces is shown in fig. 4.14.

Resolving all the forces horizontally, i.e. along East-West line,

$$\Sigma H = 25 \cos 30° + 20 \cos 90° + 35 \cos 135° + 45 \cos 225°$$
$$= 21.65 + 0 + (-24.75) + (-31.82)$$
$$= -34.92 \text{ N}$$

and resolving all the forces vertically, i.e. along North-South line,

$$\Sigma V = 25 \sin 30° + 20 \sin 90° + 35 \sin 135° + 45 \sin 225°$$
$$= 12.5 + 20 + 24.75 + (-31.82) = 25.43 \text{ N}$$

Thus, magnitude of the resultant force,

$$R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2}$$
$$= \sqrt{(-34.92)^2 + (25.43)^2}$$
$$= \mathbf{43.2\ N} \qquad \textbf{Ans.}$$

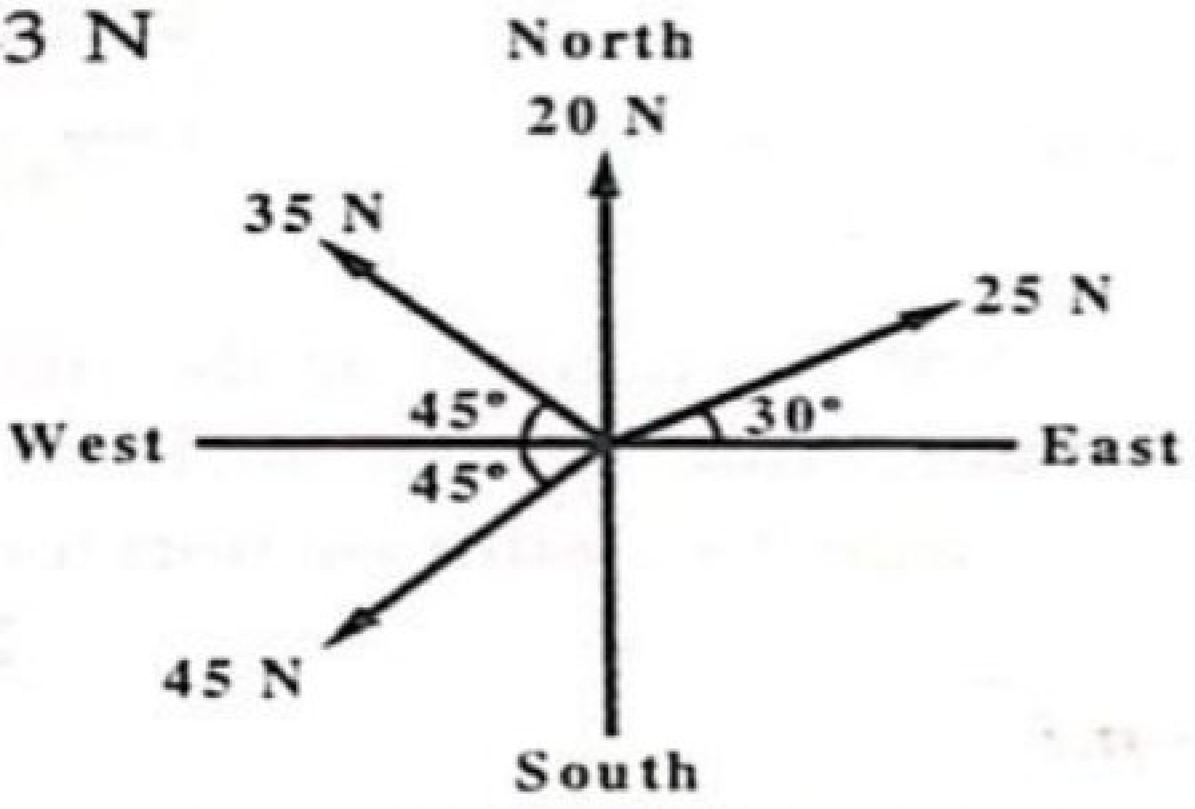


Fig. 4.14

and direction of the resultant force,

$$\alpha = \tan^{-1}\left(\frac{\Sigma V}{\Sigma H}\right)$$
$$= \tan^{-1}\frac{25.43}{-34.92} = \tan^{-1}(-0.7282) = -36.06°$$

Since ΣH is negative and ΣV is positive, therefore resultant will lie in second quardrant, i.e. between 90° and 180°. Thus actual angle of the resultant

$$= 180° - 36.06° = \mathbf{143.94°} \qquad \textbf{Ans.}$$

Prob.2. A machine component of length 2.5 m and height 1 m is carried upstairs by two men, who hold it by front and back edges of its lower face. If the machine component is inclined at 30° to the horizontal and weights 100 N, find how much of the weight each man shares. (R.G.P.V., June 2013)

Sol. The free body diagram of the machine component is shown in fi 4.15. Let P and Q be the weight shared by men holding it.

Considering equilibrium of various forces

$$P + Q - 100 = 0$$

or $$P + Q = 100 \qquad ...(i)$$

Now taking moments of various forces about point A,

$$-100 \times \frac{2.5}{2} \cos 30^\circ + Q \times 2.5 \cos 30^\circ = 0$$

or $$Q - 50 = 0$$

or $$\mathbf{Q = 50\ N} \qquad \textbf{Ans.}$$

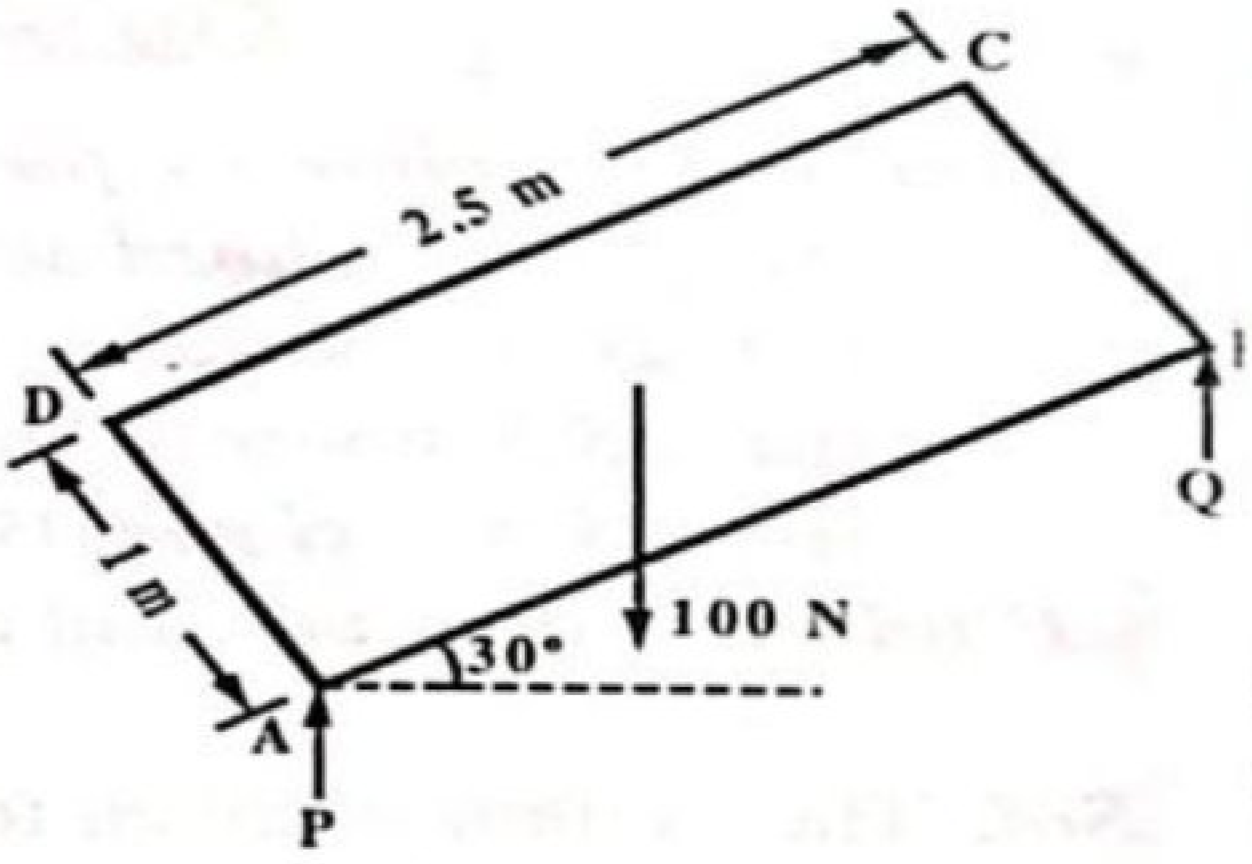


Fig. 4.15

and from equation (i),

$$P + 50 = 100$$

$$\therefore \qquad \mathbf{P = 50\ N} \qquad \textbf{Ans.}$$

Thus each man will share equal weight of the machine component.

Prob.3. A rod ABCD is acted upon by different forces as shown in fi 4.16. Find the magnitude, direction and position of the resultant force.

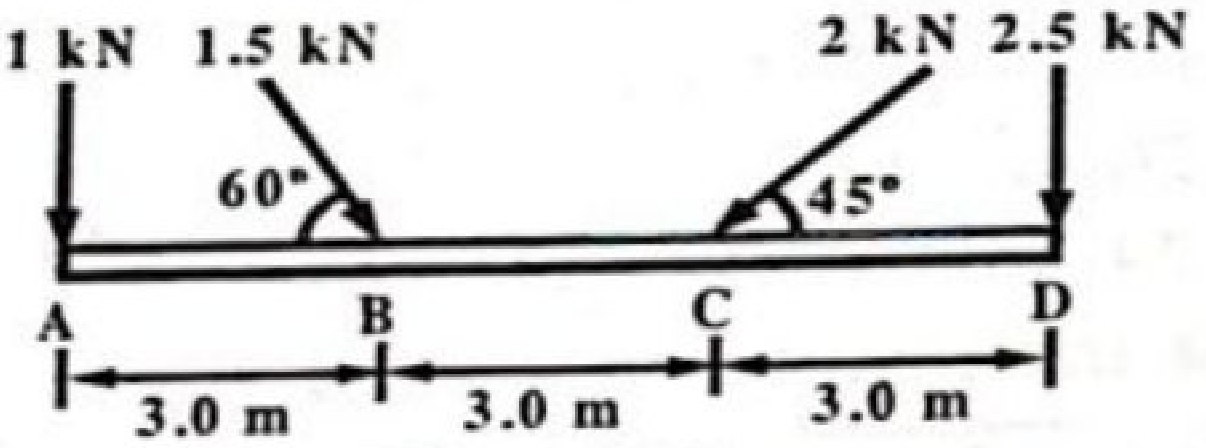


Fig. 4.16 ***(R.G.P.V., June 200***

Sol. To determine the magnitude of resultant force we have to determin the algebraic sum of horizontal and vertical forces.

Algebraic sum of horizontal component of forces,

$$\Sigma H = 1.5 \cos 60^\circ - 2 \cos 45^\circ$$
$$= 0.75 - 1.414 = -0.664 \text{ kN}$$

and algebraic sum of vertical component of forces,

$$\Sigma V = 1 + 1.5 \sin 60^\circ + 2 \sin 45^\circ + 2.5$$
$$= 1 + 1.299 + 1.414 + 2.5$$
$$= 6.213 \text{ kN}$$

$\therefore$ Magnitude of resultant, $R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2}$

$$= \sqrt{(-0.664)^2 + (6.213)^2} = \mathbf{6.248\ kN}\ \textbf{Ans}$$

Direction of resultant, $\alpha = \tan^{-1} \dfrac{\Sigma V}{\Sigma H} = \tan^{-1} \dfrac{6.213}{-0.664} = \mathbf{-83^\circ 54'}$

Ans

As ΣH is –ve and ΣV is +ve, resultant will act upward as shown in fig. 4.17.

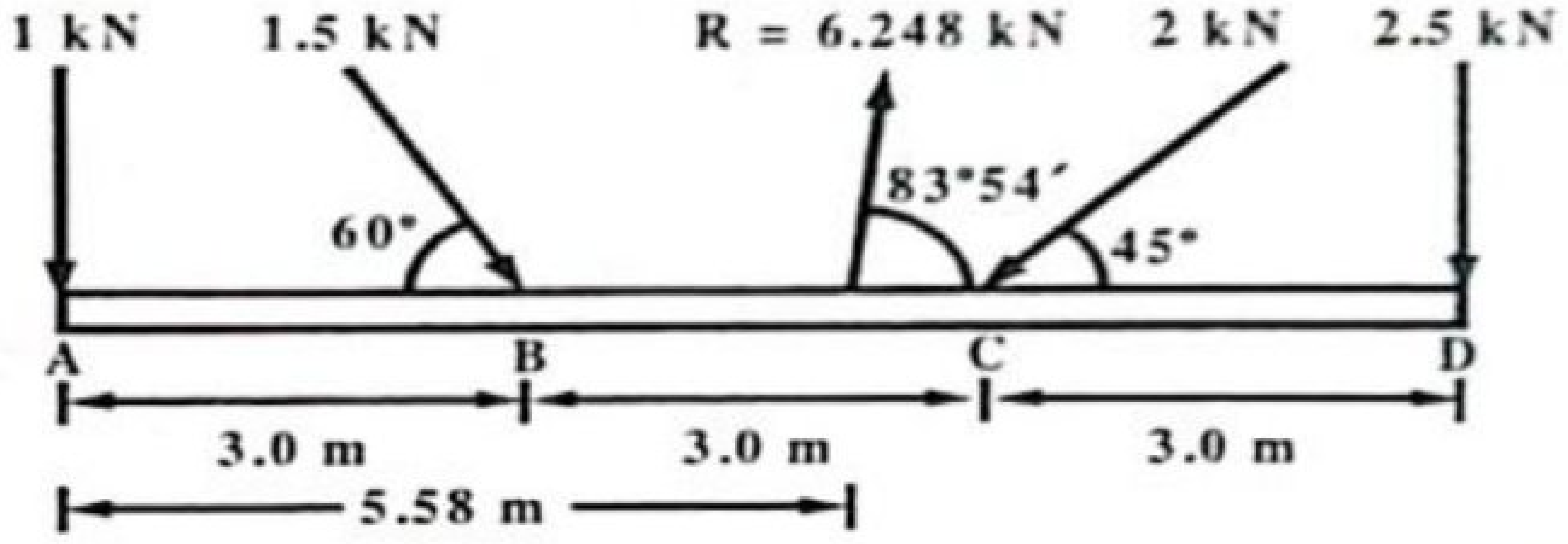


Fig. 4.17

Now location of resultant can be found by applying Varignon's theorem taking moment about point A. Let resultant R be acting at a distance x m from A. Thus,

Moment of resultant about A = Sum of moment of all individual forces about A

$$R \times x = 1.5 \sin 60^\circ \times 3 + 2 \times \sin 45^\circ \times 6 + 2.5 \times 9$$

$$6.248 \times x = 3.897 + 8.485 + 22.5$$

$$= 34.882$$

$$\therefore \quad x = \frac{34.882}{6.248} = \mathbf{5.58\ m} \qquad \textbf{Ans.}$$

Thus, resultant of 6.248 kN will act upward at a distance of 5.58 m from point A, as shown in fig. 4.17.

Prob.4. A prismatic bar of length 2.1 m and weight 365 N rests within a hemispherical bowl of radius 0.7 m as shown in fig. 4.18. Determine angle α for position of equilibrium.

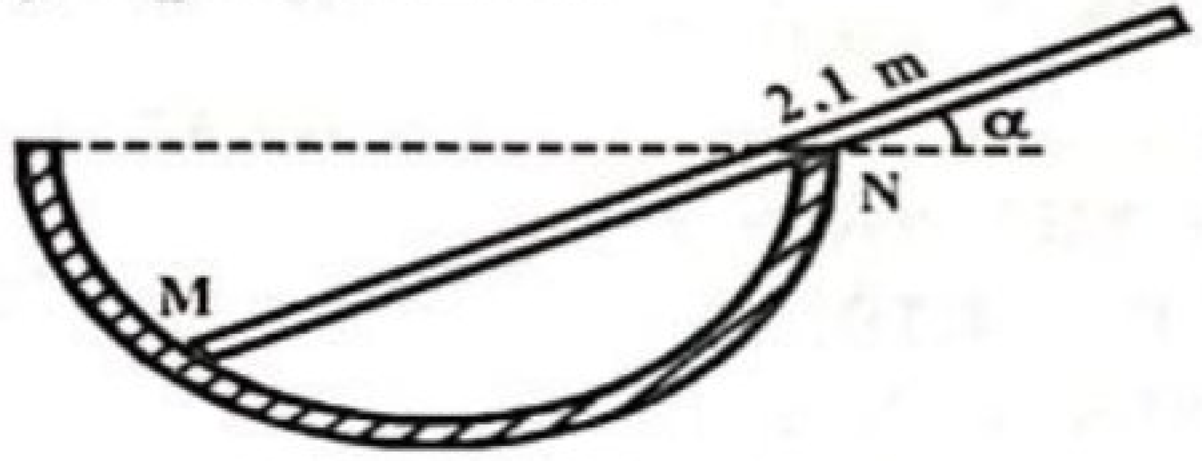


Fig. 4.18

(R.G.P.V., June 2014)

Sol. Given, $l = 2.1$ m, W = 365 N, r = 0.7 m.

The prismatic bar will be in equilibrium under the action of following three forces –

(i) Weight of prismatic bar, 365 N.
(ii) Normal reaction at point M, R_M.
(iii) Normal reaction at point N, R_N.

Let line of action of these three forces intersect at point O as shown in fig. 4.19.

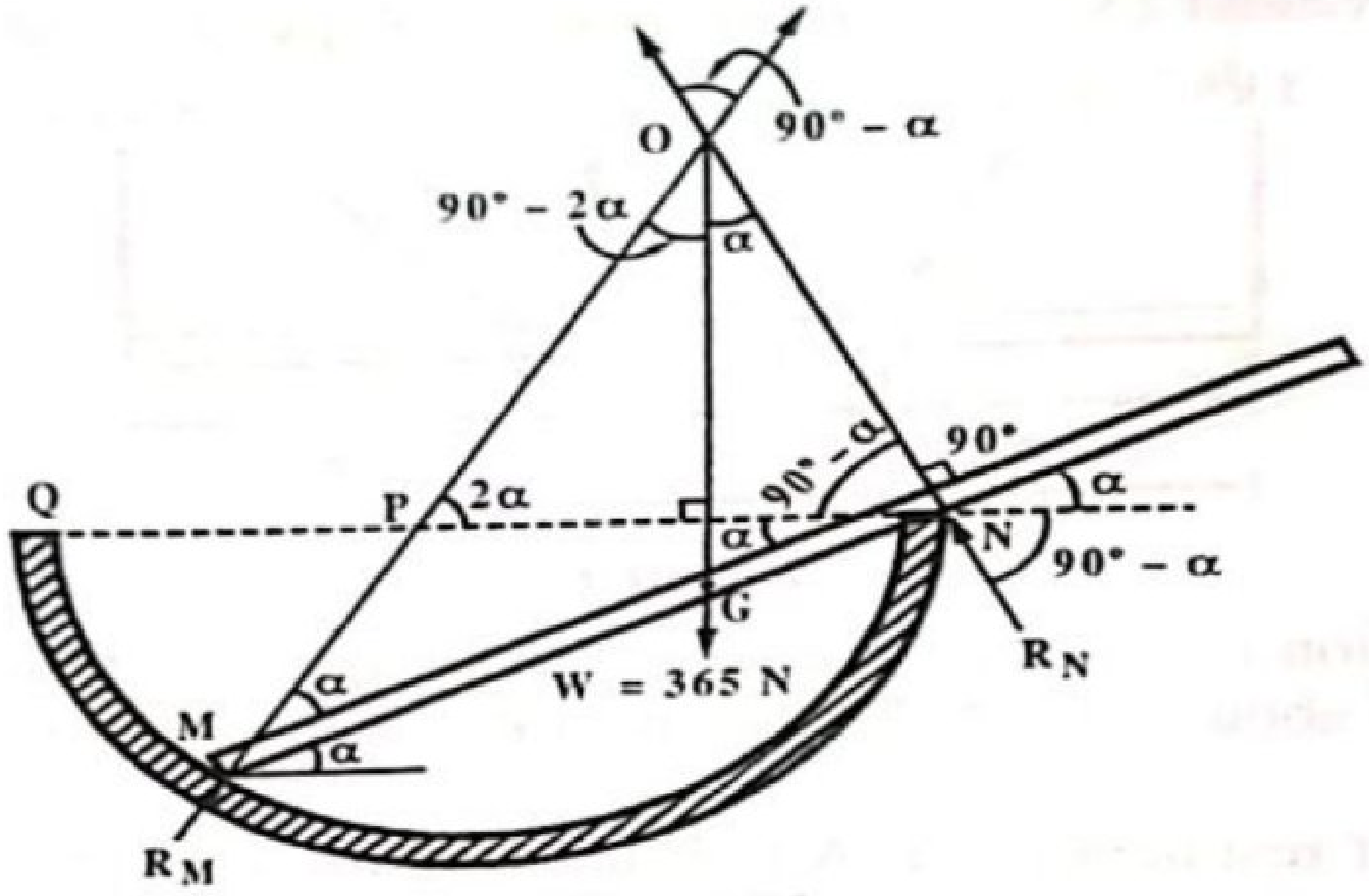


Fig. 4.19

Free body diagram of point O is shown in fig. 4.20. Applying Lami's theorem, we get

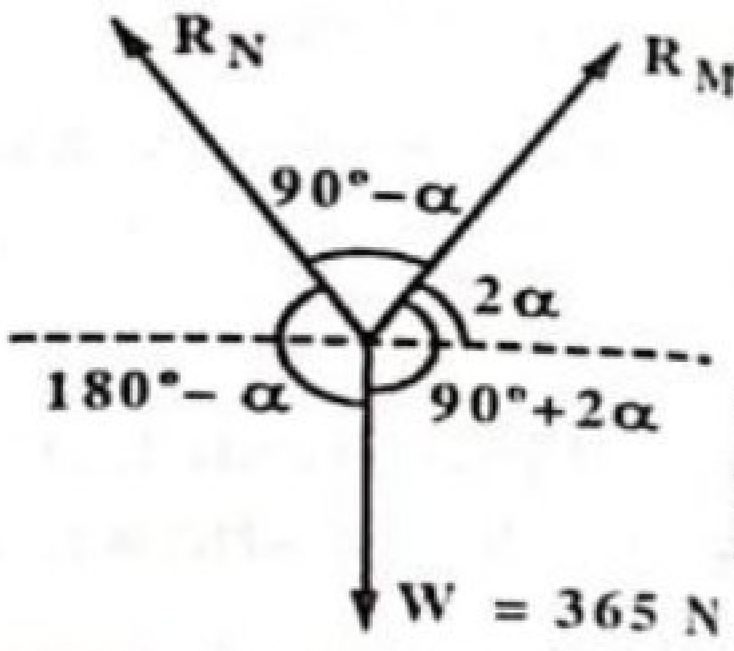


Fig. 4.20

$$\frac{365}{\sin(90^\circ-\alpha)} = \frac{R_M}{\sin(180^\circ-\alpha)} = \frac{R_N}{\sin(90^\circ+2\alpha)}$$

$$\therefore \quad R_M = \frac{365}{\sin(90^\circ-\alpha)} \times \sin(180^\circ-\alpha)$$

$$= \frac{365}{\cos\alpha} \times \sin\alpha = 365 \tan\alpha$$

and $$R_N = \frac{365}{\sin(90^\circ-\alpha)} \times \sin(90^\circ+2\alpha) = \frac{365\cos2\alpha}{\cos\alpha}$$

Taking moment of various forces about point M and equating to zero, we g

$$- R_N \times MN + W \times MG \cos\alpha = 0 \quad ....(i$$

From geometry of fig. 4.19,

$$MN = 2r \cos\alpha$$

$$= 2 \times 0.7 \cos\alpha = 1.4 \cos\alpha$$

and $$MG = \frac{l}{2} = \frac{2.1}{2} = 1.05\,\text{m}$$

Substituting various values in equation (i), we get

$$-\frac{365\cos2\alpha}{\cos\alpha} \times 1.4\cos\alpha + 365 \times 1.05\cos\alpha = 0$$

or $$-1.4 \cos 2\alpha + 1.05 \cos\alpha = 0$$

or $$1.4 \cos 2\alpha - 1.05 \cos\alpha = 0$$

or $$1.4 (2\cos^2\alpha - 1) - 1.05 \cos\alpha = 0$$

$$2.8 \cos^2\alpha - 1.05 \cos\alpha - 1.4 = 0$$

On solving above equation, we get

$$\cos \alpha = 0.919 \text{ or } -0.544$$

$$\therefore \quad \alpha = 23.2^\circ \text{ or } 122.96^\circ$$

Since $\alpha = 122.96^\circ$ is not possible, therefore we will take

$$\alpha = 23.2^\circ$$ **Ans.**

FREE DIAGRAM, FORCE DIAGRAM AND BOW'S NOTATIONS, APPLICATION OF EQUILIBRIUM CONCEPTS

Q.28. Define concept of free body diagram. Also show its applications. ***(R.G.P.V., Dec. 2015)***

Or

Define free body diagram. ***(R.G.P.V., June 2016)***

Or

Define the term free body diagram and state the importance of such a diagram. ***(R.G.P.V., Jan./Feb. 2008)***

Or

Explain the free body diagram. ***[R.G.P.V., June 2008 (O), 2011]***

Ans. A body in equilibrium is subjected to a number of external forces and reactive forces, provided by the supports. The equilibrium of such bodies may be considered by removing the supports and replacing them by reactions, which they exert on the body. The body so isolated from the system is called as a ***free body.*** When this isolated body is drawn, with all the forces and reactive forces acting on it, such a diagram is called a ***free body diagram.***

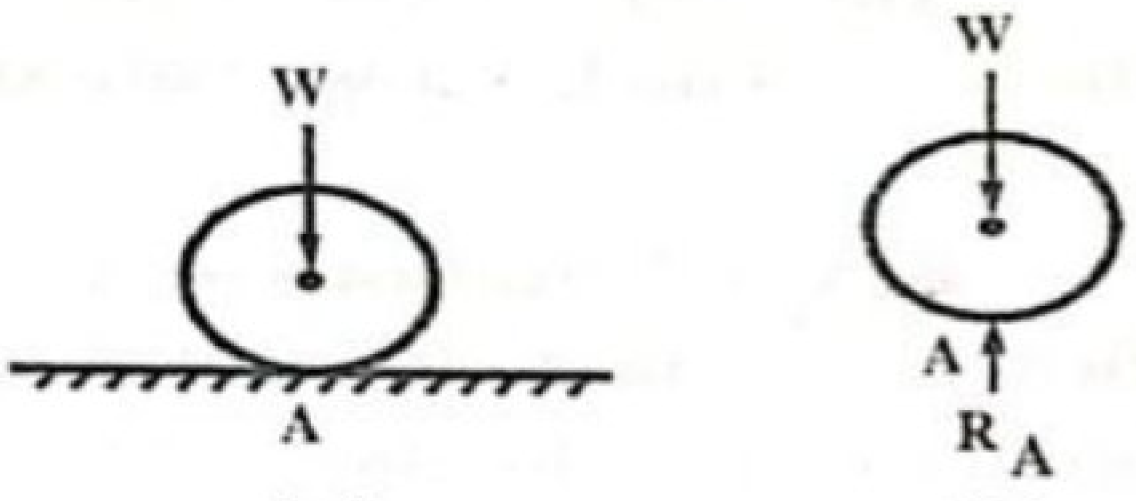
Free body diagrams are found to be very useful when two or more bodies forming a system are subjected to more than three forces. In such cases equilibrium equations for each body can be formed by drawing its free body diagram.

Q.29. Explain the term free body diagram. Draw the free body diagram of a ball of weight W, if ball placed on a horizontal surface. ***(R.G.P.V., June 2010)***

Ans. For definition of free body diagram, refer Q.28.

Consider a ball of weight W placed on a horizontal surface as shown in fig. 4.21 (a).

The support will exert a normal reaction (R_A) to the body. The point of application of R_A will be the point of contact, i.e. A. Now according to the principle of equilibrium of forces reaction R_A must be equal and opposite to weight W. The free body diagram of the ball which can be obtained after removing the support is shown in fig. 4.21 (b).



(a) ***(b)***

Fig. 4.21

Q.30. *A body of weight W is resting on a rough inclined plane. Dra body diagram of the body. Write also equations of equilibrium.*
(R.G.P.V., June 201

Ans. A body resting on a rough inclined plane as shown in fig. 4.22 wi subjected to following forces –

(i) Weight of the body acting vertically downwards.

(ii) Normal reaction, acting perpendicular to the inclined plane.

(iii) Friction force acting along the plane.

Now as long as the angle of inclination of plane (α) is less than the angle of friction (ϕ), the body will remain at rest. In this position the tangential component of the body's weight W will tend to slide the body in downward direction, but frictional force will oppose this motion.

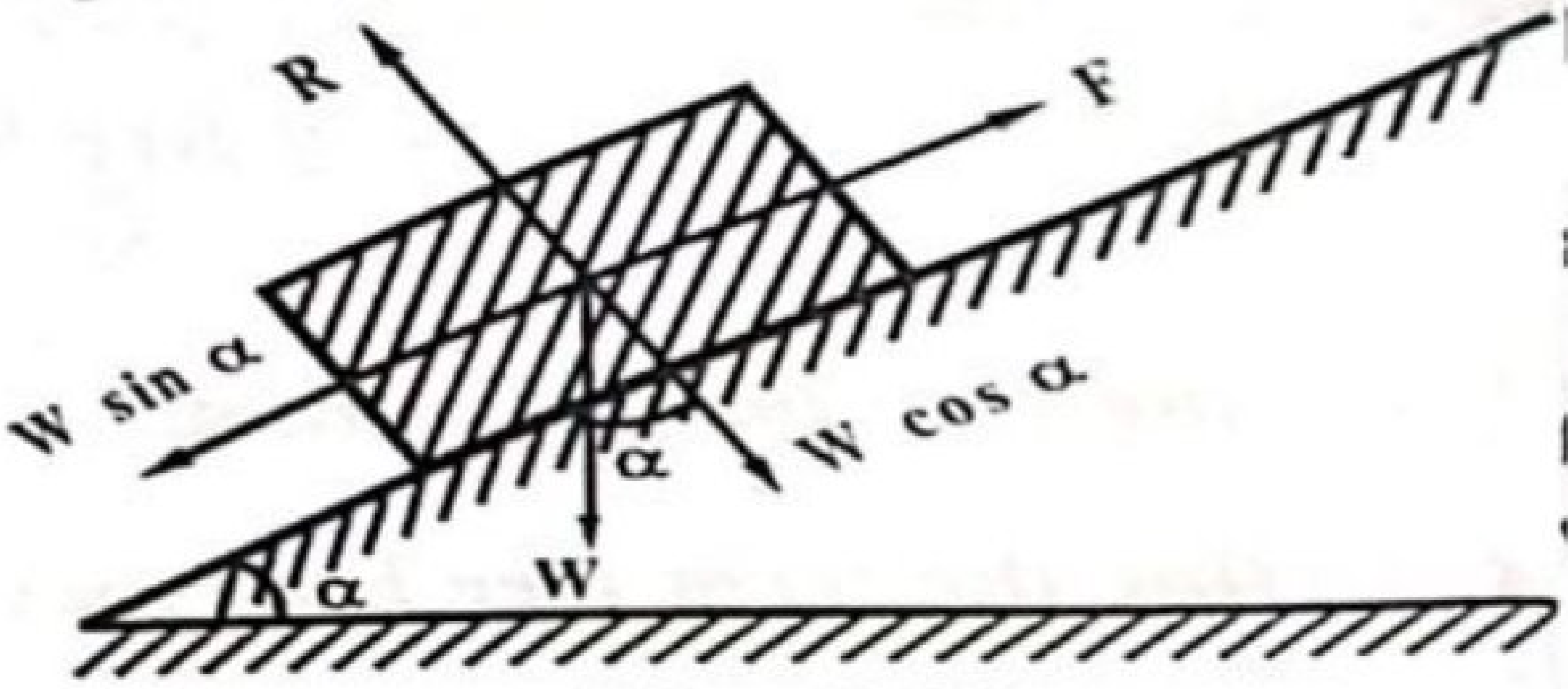


Fig. 4.22

Resolving the forces along the inclined plane, we have

$$F = \mu R = W\sin\alpha$$

or $$W\sin\alpha - \mu R = 0 \quad \text{...(i}$$

and on resolving the forces along a plane perpendicular to the inclined plan we get

$$R = W\cos\alpha$$

or $$W\cos\alpha - R = 0 \quad \text{...(ii}$$

Equations (i) and (ii) are the required equations of equilibrium.

Q.31. What do you mean by free diagram and force diagram ?
(R.G.P.V., Dec. 2016

Ans. **Free Diagram** – Refer Q.28.

Force Diagram – Force diagram is constructed by starting from an convenient point and then go on adding all the forces vectorially one by one t some suitable scale. It is also called as the vector diagram.

Q.32. What do mean by space diagram ? Also define Bow's notations

Ans. **Space Diagram** – For a system of forces, a space diagram is diagram which shows various forces alongwith their magnitudes and lines o action.

Bow's Notations – All the forces in space diagram are named by using Bow's notation. In Bow's notation, a force is represented by two alphabe letters placed in space on either side of the force. The placing of letters is either done clockwise or anticlockwise. Force between letter A and B is called as force AB and that between B and C force BC and so on.

Q.33. Write short note on – Funicular polygon.

Ans. Any portion of the cable between successive concentrated loads (fig. 4.23) is a two force member and internal force at any point of a cable is a tensile force directed along the cable. The shape of the cable so formed under these conditions is known as funicular polygon. Force polygon method cannot be used for parallel force system as it does not give the location of the resultant. Funicular polygons are thus used which locates the resultant of parallel force system in space.

Funicular polygon for a system of parallel forces as shown in fig. 4.24 can be drawn as follows –

(i) First of all a space diagram as shown in fig. 4.25 (a) is drawn which shows various forces along with their magnitudes and lines of action.

(ii) Now forces in space diagram are named according to Bow's notation.

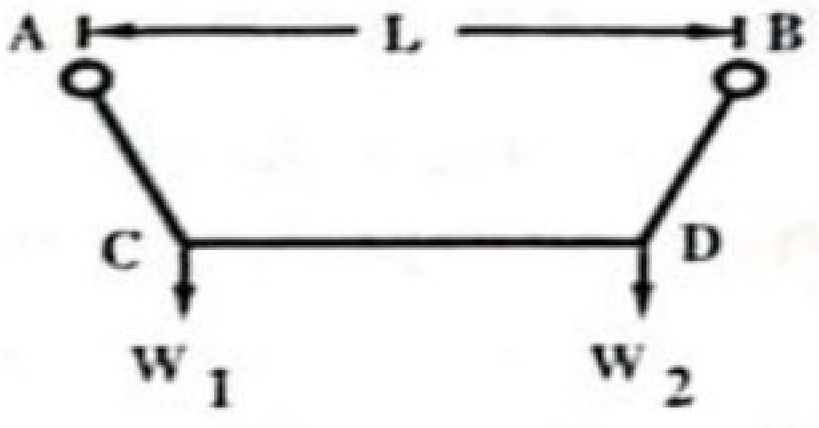


Fig. 4.23

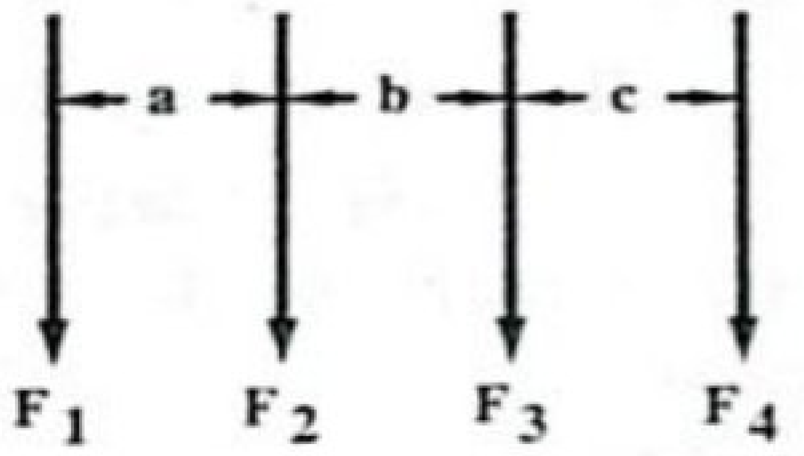
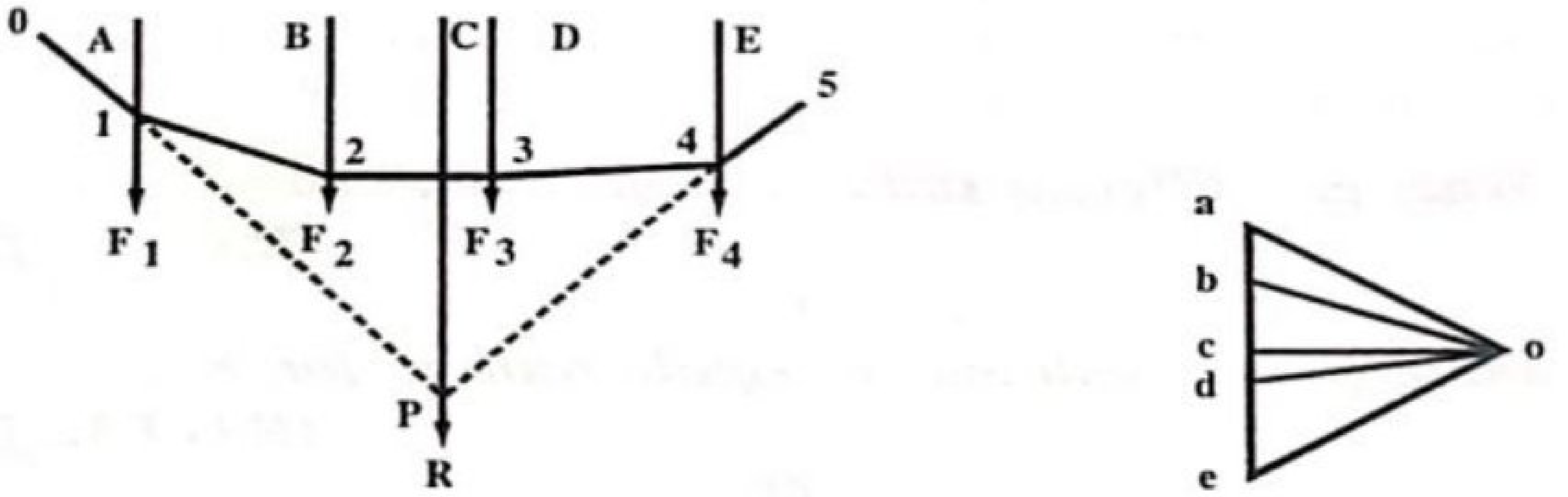


Fig. 4.24

(iii) A suitable point is selected in space and starting from force AB all the forces are added vectorially one by one on some convenient scale.

(iv) Another suitable point o is selected and oa, ob, oc, od and oe are joined. The resultant diagram as shown in fig. 4.25 (b) is called vector or force diagram.



(a) Space Diagram ***(b) Vector Diagram***

Fig. 4.25

(v) Take some suitable point 0 in space and from 0 draw a line parallel to ao of the vector diagram, which intersects line of action of force AB at 1.

(vi) Now through 1 draw a line 1-2 parallel to bo which meets line of action of force BC at 2. Similarly, through 2 draw 2-3 parallel to co, through 3 draw 3-4 parallel to do, and through 4 draw 4-5 parallel to eo. This continuous chain of lines 0-1-2-3-4-5 is known as the ***funicular polygon.***

(vii) Now extend 0-1 and 4-5 meeting each other at point P. Through P draw a line parallel to force AB, BC......etc.

(viii) Now magnitude of resultant force will be given by,

$$R = \text{Length ac} \times \text{Chosen scale}$$

and the location of resultant will be given by perpendicular distance betwe force AB and resultant.

Q.34. When a body is said to be in equilibrium ? What are the variou types of equilibrium ?

Ans. A body is said to be in equilibrium, when the resultant of the syste of forces acting on it is zero. If a body is in equilibrium, it will continue i state of rest or uniform motion.

Types of Equilibrium – There are following three types of equilibrium

(*i*) ***Stable Equilibrium*** – A body is said to be in stable equilibriu if it returns back to its original position, after it is slightly disturbed from i position of rest. In this case the restoring force acts in the opposite directi to the displacing force.

(ii) Unstable Equilibrium – A body is said to be in unstable equil brium, if it does not return back to its original position of rest, after it slightly disturbed. In this case restoring force acts in the direction of displaci force.

(iii) Neutral Equilibrium – A body is said to be in neutral equilibriu if it occupies a new position, and remains at rest in this new position, after is slightly disturbed from its original position. In this case no additional for sets up due to the displacement.

Q.35. What are different statically equilibrium conditions ? Explain
(R.G.P.V., Dec. 201

Or

State and explain conditions of equilibrium of forces.
(R.G.P.V., Dec. 201

Or

Explain the conditions of equilibrium.
(R.G.P.V., June 2007, Sept. 2009, June 2011, 201

Ans. Various conditions of equilibrium of a body subjected to a system forces can be classified into following two types –

Analytical Conditions of Equilibrium – The necessary and sufficie conditions for a system of coplanar forces acting on a rigid body to keep it i equilibrium are –

(i) The algebraic sum of the resolved parts of the forces actin along X-axis is zero, i.e.

$$\Sigma F_X = 0 \qquad \ldots($$

(ii) The algebraic sum of the resolved parts of the forces acting long Y-axis is zero, i.e.

$$\Sigma F_Y = 0 \qquad ...(ii)$$

(iii) The algebraic sum of the moments of all the forces about any oint in their plane is zero, i.e.

$$\Sigma M = 0 \qquad ...(iii)$$

This condition can also be said as for a body in equilibrium the sum of the lockwise moments is equal to the sum of the anticlockwise moments.

Conditions (i) and (ii) can combinely be written as, the algebraic sum of he all forces is equal to zero, i.e.

$$\Sigma F = 0 \qquad ...(iv)$$

Equation (iv) is known as the ***force law of equilibrium,*** while equation iii) is known as the ***moment law of equilibrium.***

Graphical Conditions of Equilibrium – When all the forces acting on a body which is in equilibrium are shown by the sides of the force polygon, the polygon closes by itself. Thus, graphical conditions for equilibrium are –

(i) Force polygon will close itself.

(ii) There will be no resultant force, i.e. R = 0.

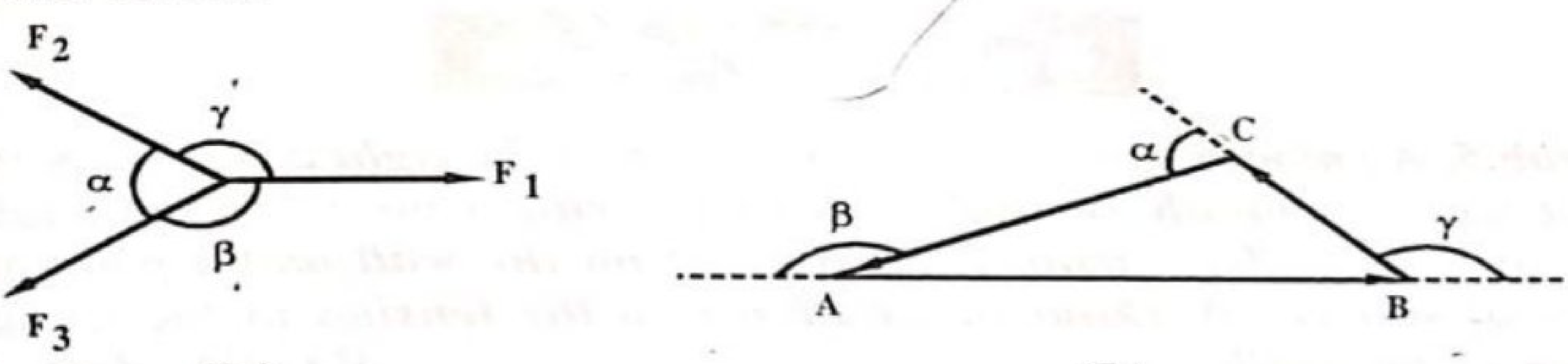
Q.36. State and prove Lami's theorem of three forces.

(R.G.P.V., Dec. 2015, June 2016)

Or

Write short note on – Lami's theorem. ***(R.G.P.V., Dec. 2017)***

Ans. Lami's theorem states, "if three coplanar forces acting at a point are in equilibrium, then each force is proportional to the sine of angle between the other two forces."



(a) *(b)*

Fig. 4.26 Lami's Theorem

If three forces F_1, F_2 and F_3 are acting at a point as shown in fig. 4.26 (a), then according to Lami's theorem

$$\frac{F_1}{\sin\alpha} = \frac{F_2}{\sin\beta} = \frac{F_3}{\sin\gamma}$$

Proof – Consider three forces F_1, F_2 and F_3 acting at a point as shown fig. 4.26 (a). A triangle ABC as shown in fig. 4.26 (b) is drawn whose sid AB, BC and CA are parallel to forces F_1, F_2 and F_3 respectively. These sid represent the three forces in magnitude and direction.

Now from geometry of the fig. 4.26 (b), we have,

$$\angle CAB = 180° - \beta$$

$$\angle ABC = 180° - \gamma$$

and

$$\angle BCA = 180° - (\angle CAB + \angle ABC)$$

$$= 180° - (180° - \beta + 180° - \gamma)$$

$$= \beta + \gamma - 180° \quad ...($$

But $\alpha + \beta + \gamma = 360°$

Subtracting 180° from both sides

$$(\beta + \gamma - 180°) + \alpha = 360° - 180°$$

$$= 180°$$

or

$$\angle BCA = 180° - \alpha$$

Now in ΔABC using sine formula, we have

$$\frac{AB}{\sin \angle BCA} = \frac{BC}{\sin \angle CAB} = \frac{CA}{\sin \angle ABC}$$

or

$$\frac{F_1}{\sin(180°-\alpha)} = \frac{F_2}{\sin(180°-\beta)} = \frac{F_3}{\sin(180°-\gamma)}$$

or

$$\frac{F_1}{\sin \alpha} = \frac{F_2}{\sin \beta} = \frac{F_3}{\sin \gamma}$$

This proves the Lami's theorem.

NUMERICAL PROBLEMS

Prob.5. A smooth sphere of radius 15 cm and weight 2 N is supported contact with a smooth vertical wall by a string whose length equals t radius of sphere. The string joins a point on the wall and a point on t surface of sphere. Workout inclination and the tension in the string a reaction of the wall. ***(R.G.P.V., Dec. 201***

Sol. Given, r = 15 cm, W = 2 N, $l = r = 15$ cm.

The sphere as shown in fig. 4.27 will be in equilibrium under the action following three forces –

(i) Weight of the sphere acting vertically downwards.

(ii) Tension in the string, T.

(iii) Normal reaction of the wall, R.

In ΔOAB, $\cos\theta = \dfrac{OB}{OA} = \dfrac{r}{r+l} = \dfrac{1}{2}$ $\quad (\because r = l)$

$$\therefore \quad \theta = \cos^{-1}\left(\frac{1}{2}\right) = 60^\circ \quad \textbf{Ans.}$$

Resolving the forces horizontally, we et

$$T\cos\theta = R \quad \text{....(i)}$$

nd resolving the forces vertically, we get

$$T\sin\theta = W \quad \text{...(ii)}$$

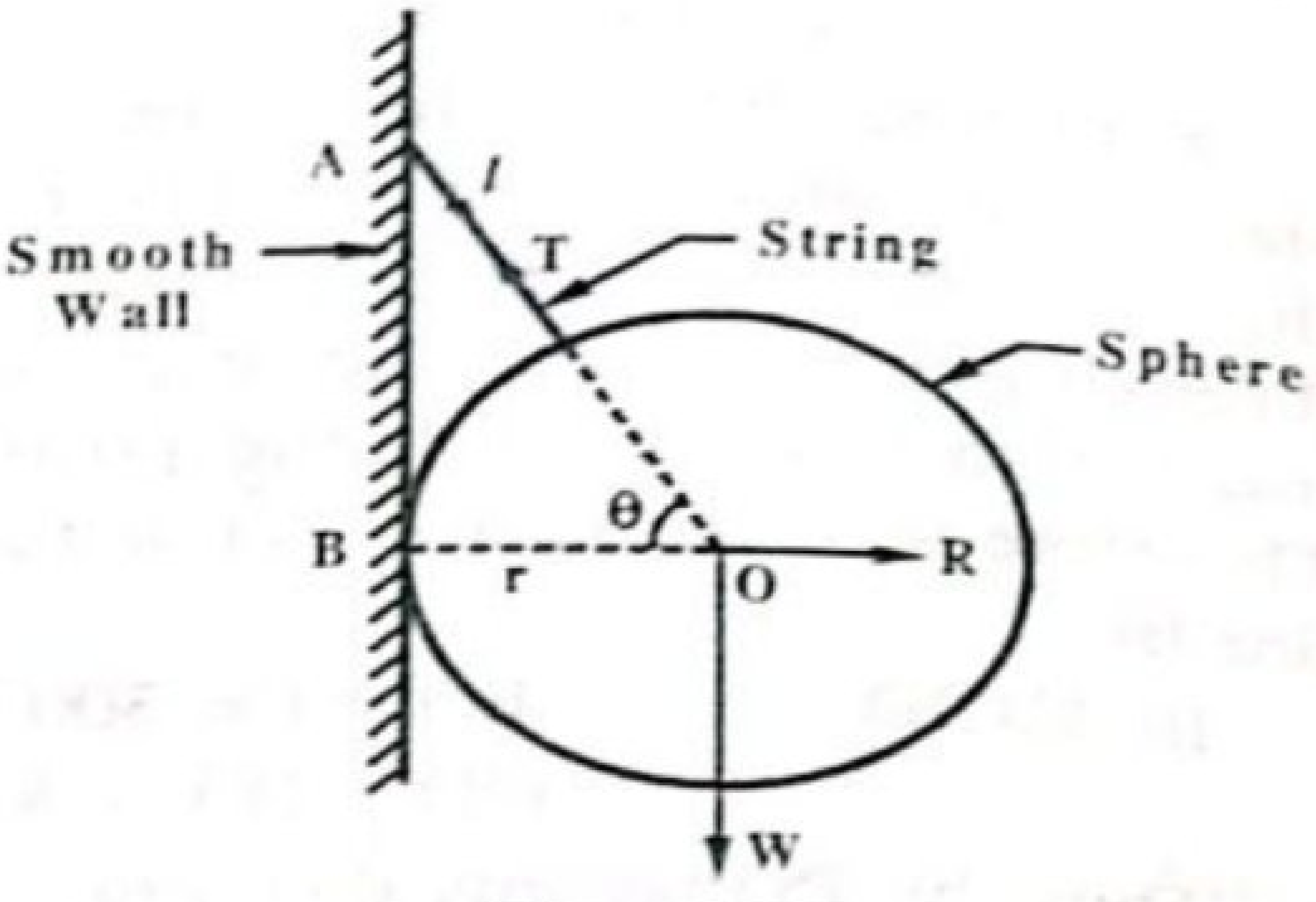


Fig. 4.27

From equation (ii),

$$T\sin 60^\circ = 2$$

$$T = \frac{2}{\sin 60^\circ} = \mathbf{2.3\ N} \quad \textbf{Ans.}$$

Substituting values in equation (i), we get

$$2.3 \times \cos 60^\circ = R$$

r $\quad R = \mathbf{1.15\ N}$ **Ans.**

Prob.6. A roller of radius, r = 300 mm and weight 2000 N is to be pulled ver a curb of height 150 mm by a horizontal force P applied to the end of tring tightly wound around the circumference of the roller. Find the nagnitude of P required to start the roller move over the curb. What is the east pull P through the centre of the wheel to just turn the roller over the urb (fig. 4.28) ?

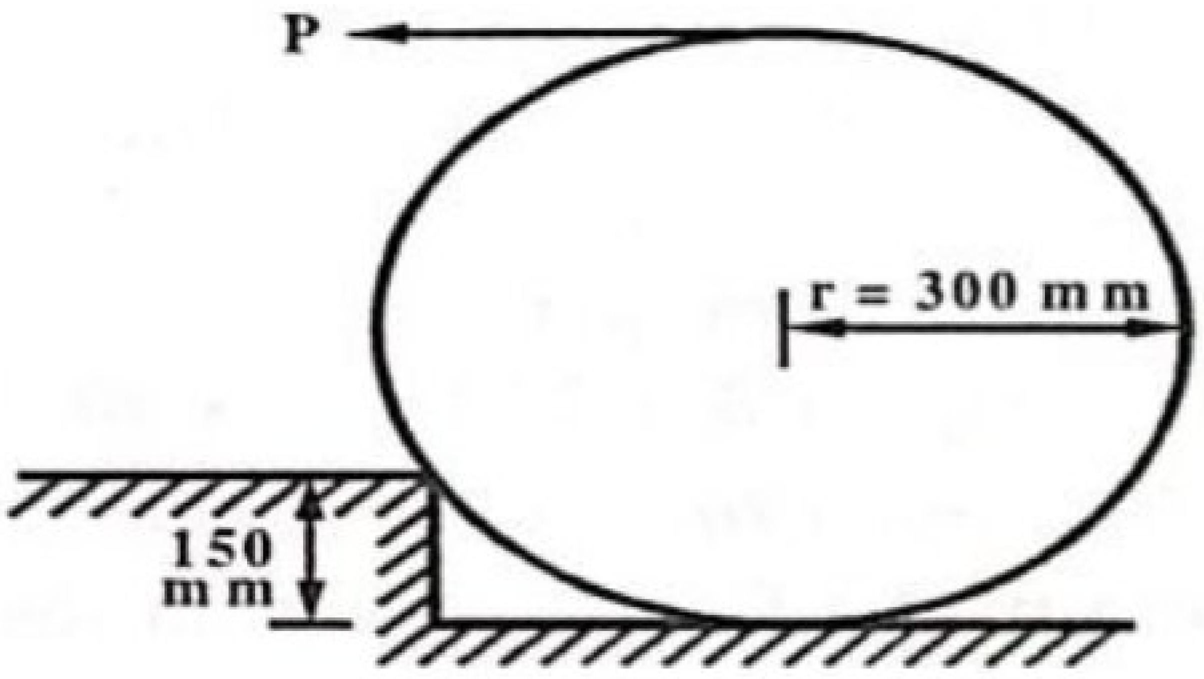


Fig. 4.28

(R.G.P.V., June 2012)

Sol. Given, W = 2000 N, r = 300 mm, height of curb, h = 150 mm.

(i) When pull is applied at the end of the string

When the roller is about to turn over the corner of the curb, the roller lifts om the floor (shown by point A in fig. 4.29) and there will be no contact at nat point. Hence reaction at point A will be zero, i.e.

Now, the roller will be in equilibrium under the action of three forces as hown in fig. 4.29 and are given below –

(a) Weight of roller W, acting vertically downward

(b) Horizontal force P

(c) Reaction R_B at point B.

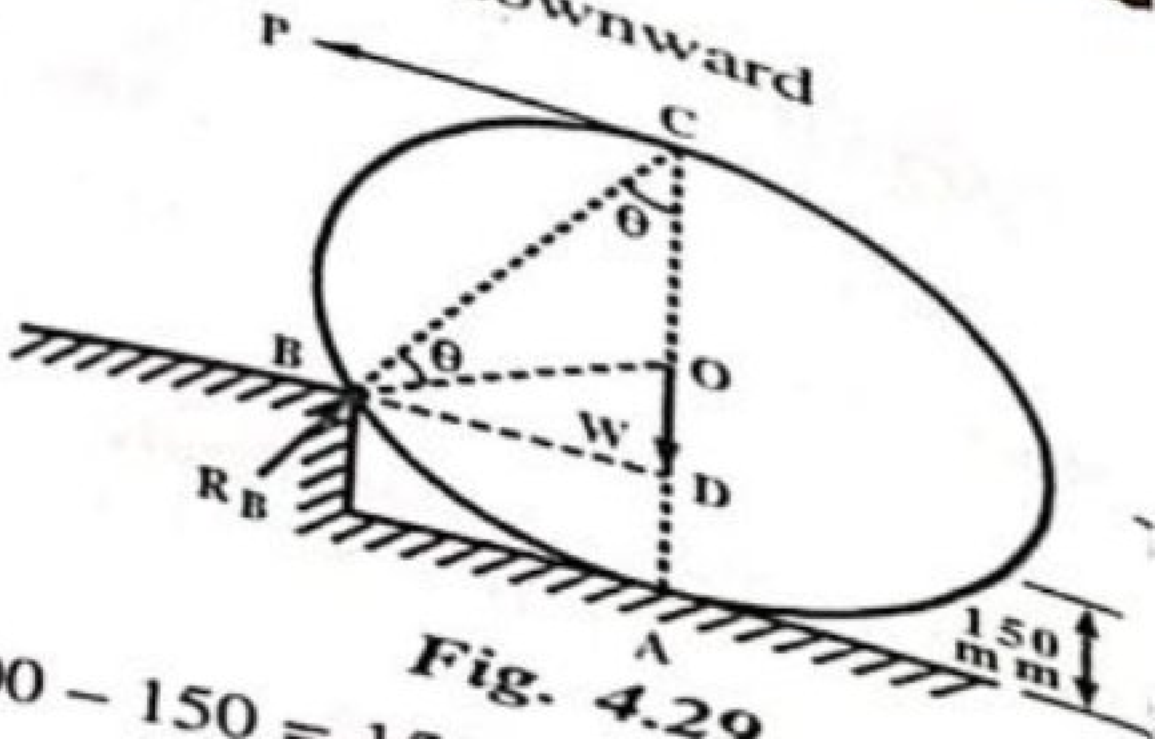


Fig. 4.29

For the equilibrium, these three forces should pass through a common point. As the force P and weight W are passing through point C, hence the reaction R_B must also pass through the point C. Therefore reaction R_B will act along the line BC.

In ΔBOD, $BO = r = 300$ mm

$$OD = OA - AD = 300 - 150 = 150 \text{ mm}$$

Thus, by Pythagorus theorem,

$$BD = \sqrt{(BO)^2 - (OD)^2}$$

$$= \sqrt{(300)^2 - (150)^2} = \sqrt{67500} = 259.8 \text{ mm}$$

Now in ΔBCD, $\tan\theta = \dfrac{BD}{CD} = \dfrac{BD}{CO + OD}$

$$\tan\theta = \frac{259.8}{300 + 150} = 0.5773$$

$$\therefore \quad \theta = \tan^{-1}(0.5773) = 30^\circ$$

Resolving forces vertically, we get

$$W = R_B \cos\theta$$

$$2000 = R_B \cos 30^\circ = 0.866\, R_B$$

$$R_B = 2309.47 \text{ N}$$

and resolving forces horizontally, we get

$$P = R_B \sin\theta = 2309.47 \times \sin 30^\circ = \mathbf{1154.7\ N}$$ A

(ii) When pull is applied through the centre of the roller

In this case, the system of the forces acting on the roller is shown in 4.30.

In this case, also the roller will be in equilibrium under the action of the three forces as shown in fig. 4.30 and are given below –

(a) Weight of roller W, acting vertically downward

(b) Horizontal force P

(c) Reaction R_B at point B.

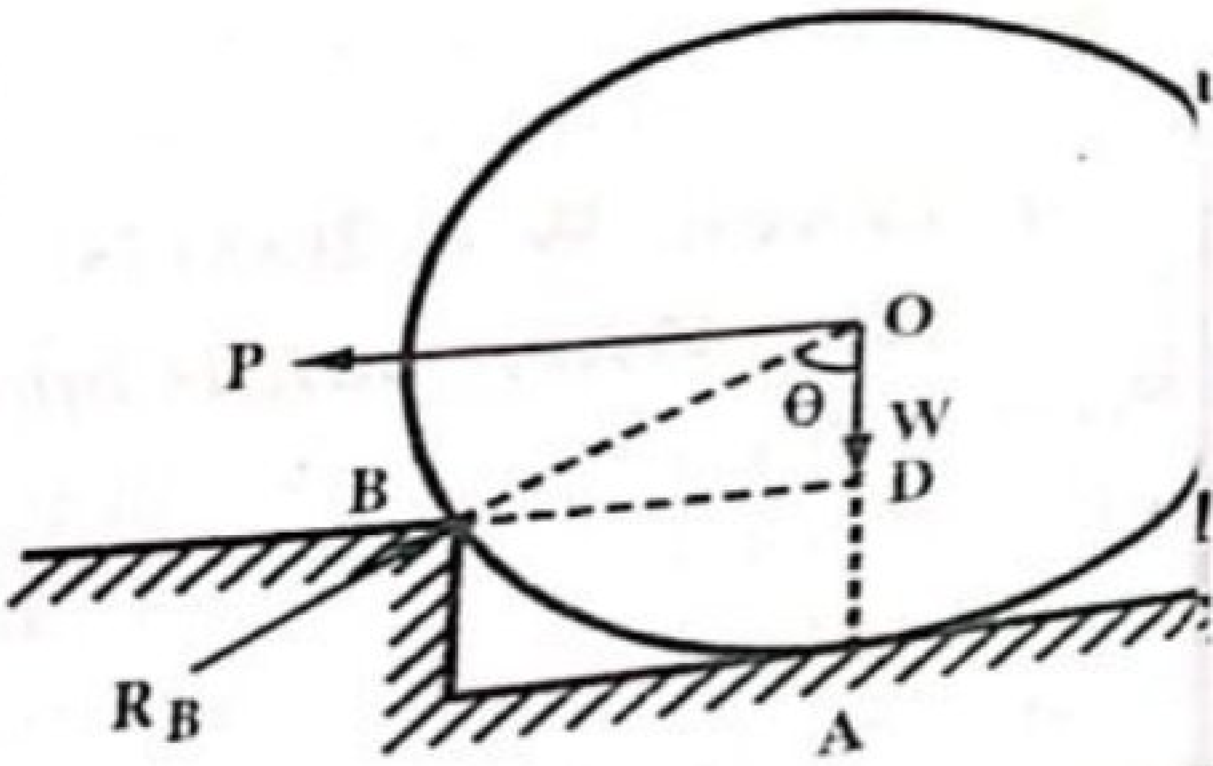


Fig. 4.30

For the equilibrium, these three forces ould pass through a common point. As the force P and weight W are passing through centre O, thus the reaction R_B must lso pass through the point O. Therefore, the R_B will act along the line BO.

In Δ BOD, $\cos\theta = \frac{OD}{BO} = \frac{150}{300} = 0.5$

$\therefore \qquad \theta = \cos^{-1} 0.5 = 60^\circ$

Resolving forces vertically, we get

$$W = R_B \cos\theta$$

$$2000 = R_B \times \cos 60^\circ = 0.5\ R_B$$

$\therefore \qquad R_B = 4000\ \text{N}$

Resolving forces horizontally, we get

$$P = R_B \sin\theta$$

$= 4000 \times \sin 60^\circ = \mathbf{3464.1\ kN}$ **Ans.**

Prob.7. A weight of 3000 N is supported by two chains AC and BC as shown in fig. 4.31 below. Determine the tension in each chain.

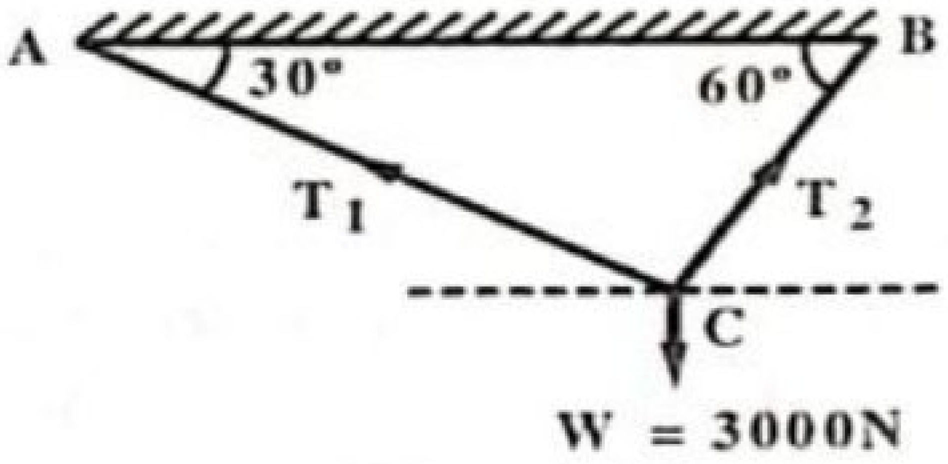


Fig. 4.31 ***(R.G.P.V., Dec. 2012)***

Sol. The system of forces at point C is shown in fig. 4.32.

Now applying Lami's theorem, we get

$$\frac{3000}{\sin 90^\circ} = \frac{T_1}{\sin 150^\circ} = \frac{T_2}{\sin 120^\circ}$$

$\therefore \qquad T_1 = \frac{3000}{\sin 90^\circ} \times \sin 150^\circ$

$= \frac{3000 \times 0.5}{1} = \mathbf{1500\ N}$ **Ans.**

nd $\qquad T_2 = \frac{3000}{\sin 90^\circ} \times \sin 120^\circ$

$= \frac{3000 \times 0.866}{1} = \mathbf{2598\ N}$ **Ans.**

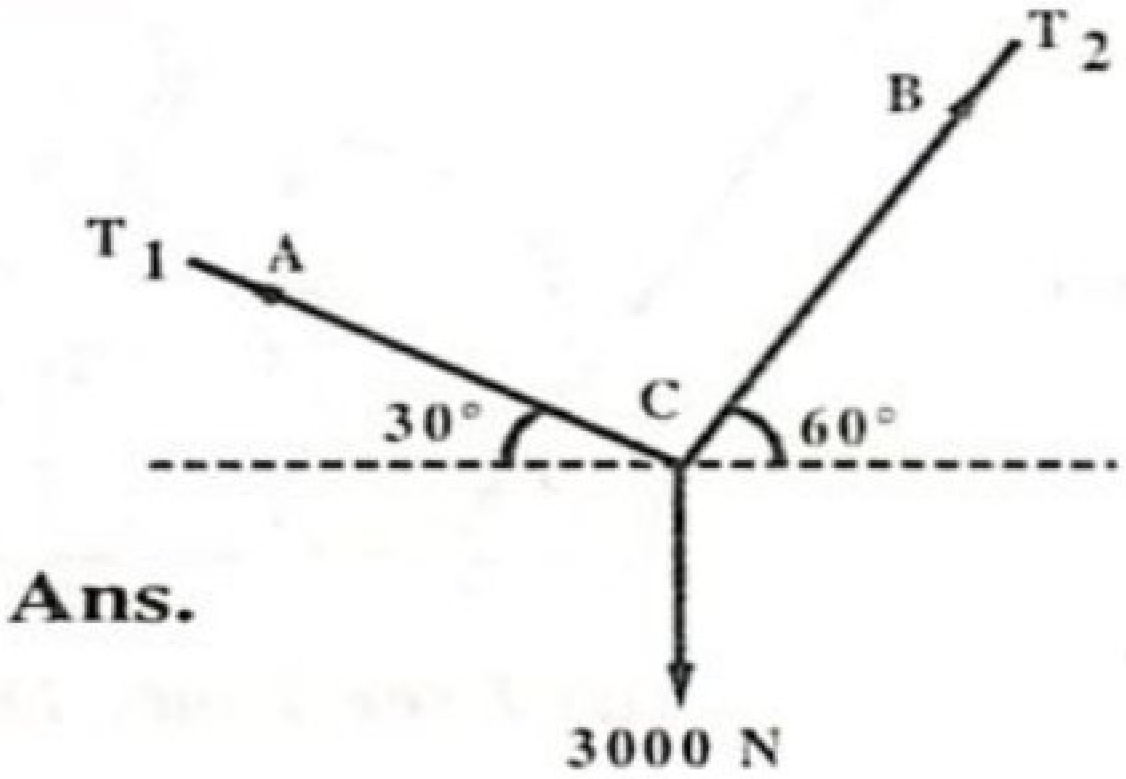


Fig. 4.32

Prob.8. Two cylinders P and Q rest in a channel as shown in fig. 4.33. The cylinder P has diameter of 100 mm and weight 200 N, whereas the ylinder Q has diameter of 180 mm and weight 600 N.

If the bottom width of the box is 180 mm, with one side vertical and the ther inclined at 60°, determine the pressures at all the four points of contact.

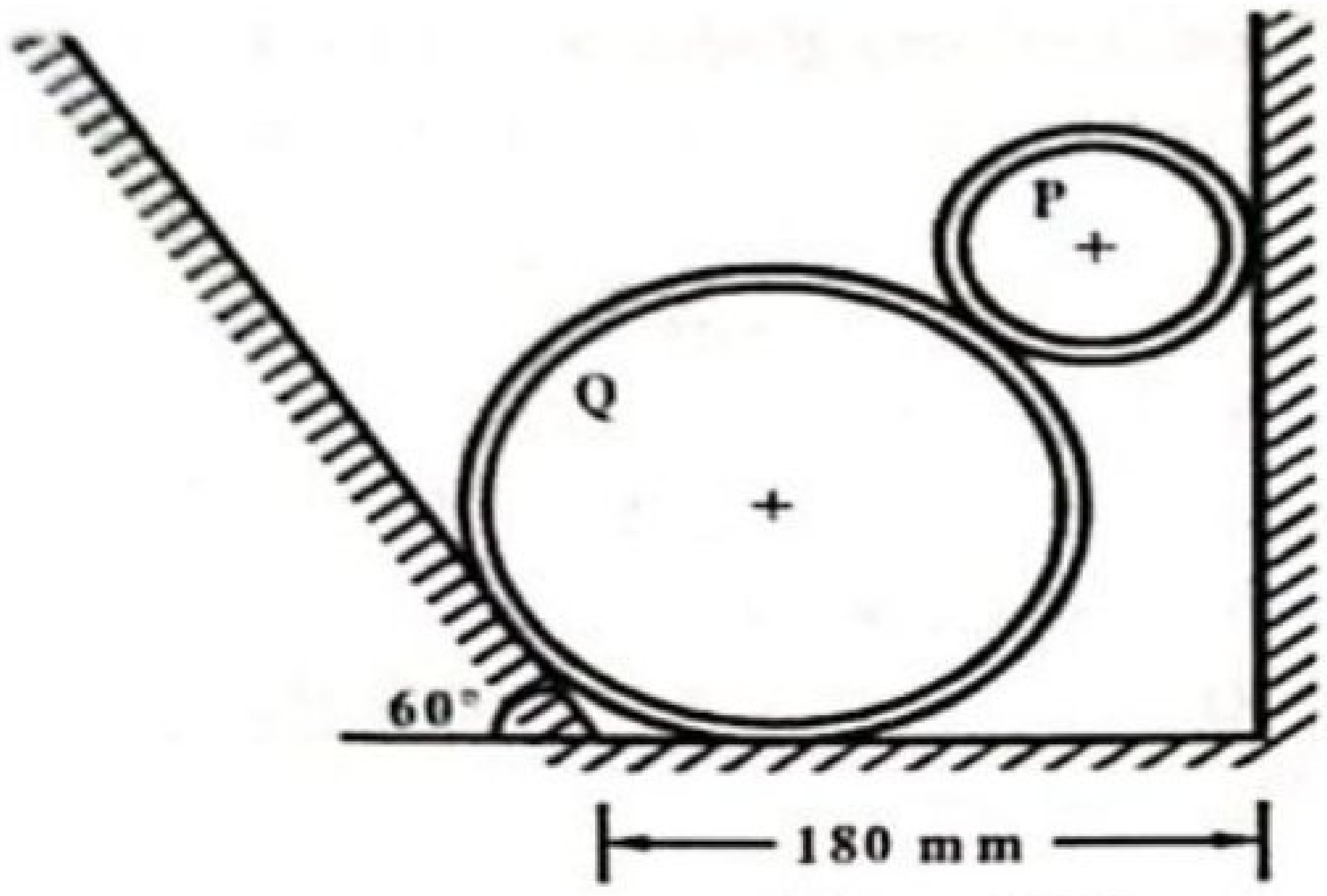


Fig. 4.33

(R.G.P.V., Jan./Feb. 20

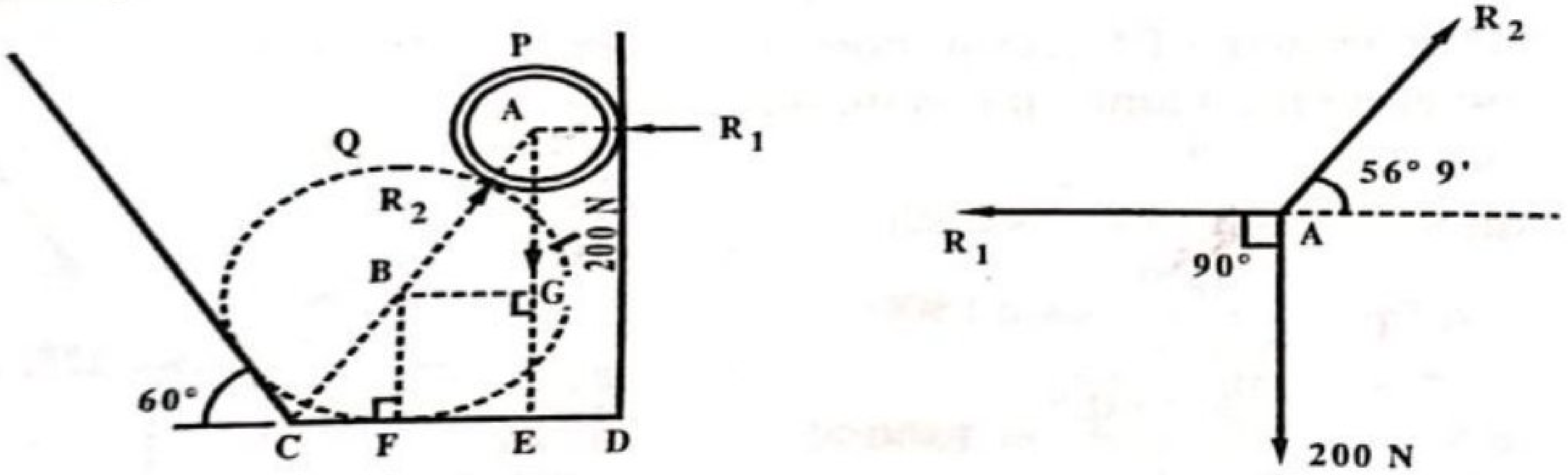
Sol. Given, Dia. of cylinder P = 100 mm, Weight of P = 200 N, Dia. cylinder Q = 180 mm, Weight of Q = 600 N, Width of box = 180 mm.

Considering equilibrium of the cylinder P. It is in the equilibrium under action of three forces which passes through its centre A, as shown in 4.34 (a) and are as follows –

(i) Weight of the cylinder 200 N acting vertically downwards

(ii) Reaction R_1 of the cylinder at the vertical side

(iii) Reaction R_2 of the cylinder P at the point of contact with cylinder Q.



(a) Free Body Diagram

(b)

Fig. 4.34

From the geometry of fig. 4.34 (a), we have

$$\angle BCF = 60^\circ$$

Now in ΔBCF

$$\tan 60^\circ = \frac{BF}{CF}$$

$$\therefore \quad CF = \frac{BF}{\tan 60^\circ} = \frac{180/2}{\sqrt{3}} = 52 \text{ mm}$$

$$ED = \frac{100}{2} = 50 \text{ mm}$$

$$\text{and} \quad FE = BG = 180 - (52 + 50) = 78 \text{ mm}$$

$$\therefore \quad AB = 50 + 90 = 140 \text{ mm}$$

$$\text{and} \quad \cos \angle ABG = \frac{BG}{AB} = \frac{78}{140} = 0.5571$$

$$\therefore \quad \angle ABG = \cos^{-1} (0.5571) = 56°9'$$

The system of forces acting at A is shown in fig. 4.34 (b).

Applying Lami's equation at A,

$$\frac{200}{\sin(180° - 56°9')} = \frac{R_1}{\sin(90° + 56°9')} = \frac{R_2}{\sin 90°}$$

$$\frac{200}{\sin 56°9'} = \frac{R_1}{\cos 56°9'} = \frac{R_2}{1}$$

$$\therefore \quad R_1 = \frac{200}{\sin 56°9'} \times \cos 56°9'$$

$$= \frac{200 \times 0.5571}{0.8305} = \mathbf{134.2\ N} \qquad \text{Ans.}$$

$$\text{and} \quad R_2 = \frac{200}{\sin 56°9'} = \frac{200}{0.8305} = \mathbf{240.8\ N} \qquad \text{Ans.}$$

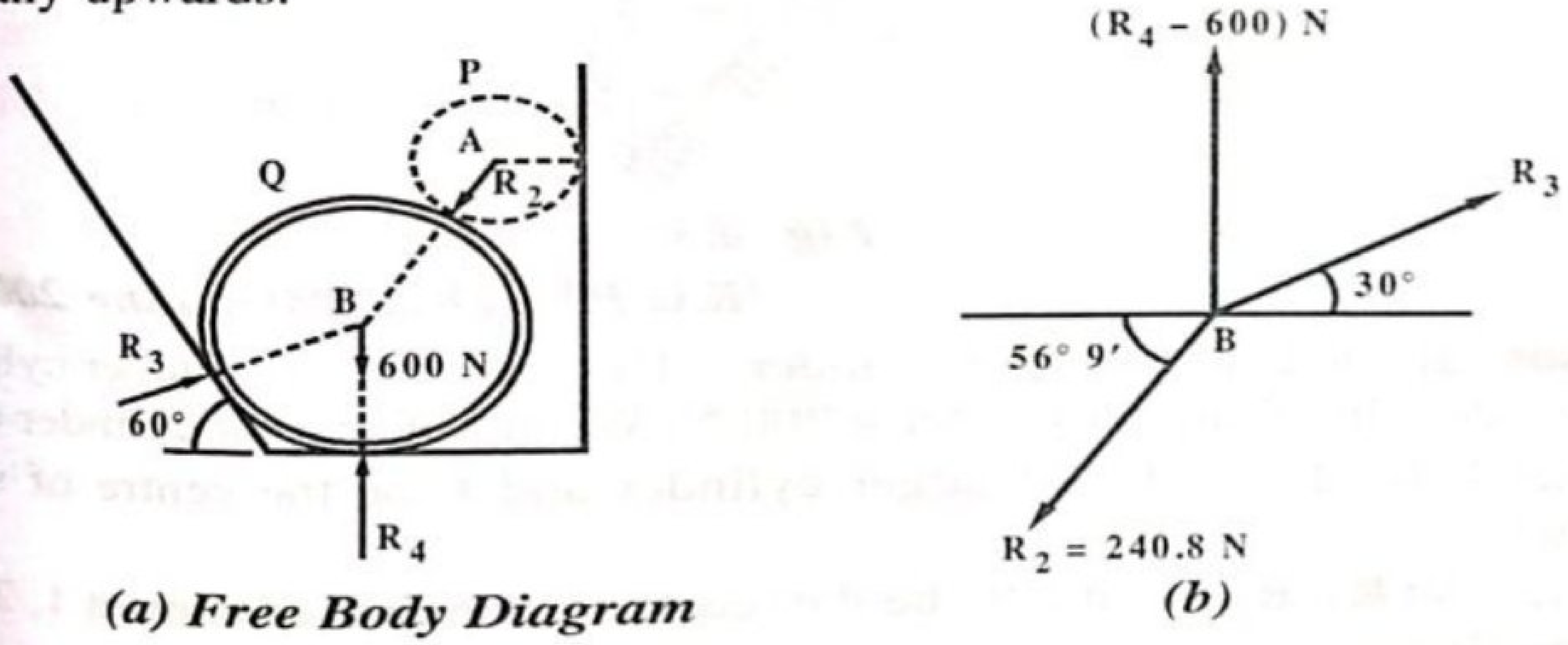
Now considering the equilibrium of the cylinder Q. It is in equilibrium under the action of four forces which passes through its centre B, as shown in fig. 4.35 (a) and are as follows –

(i) Weight of the cylinder 600 N acting vertically downwards.

(ii) Reaction $R_2 = 240.8$ N of cylinder P on the cylinder Q.

(iii) Reaction R_3 of the cylinder Q on the inclined surface.

(iv) Reaction R_4 of the cylinder Q on the base of the box, acting vertically upwards.



(a) Free Body Diagram *(b)*

Fig. 4.35

As weight of cylinder 600 N acting vertically downwards and reacti R_4 is acting vertically upwards, therefore, net vertical force acting upward $(R_4 - 600)$ N.

The system of forces acting at B is shown in fig. 4.35 (b).

Applying Lami's equation at B

$$\frac{R_3}{\sin(90^\circ+56^\circ 9')} = \frac{240.8}{\sin 60^\circ} = \frac{R_4 - 600}{\sin(180^\circ+30^\circ-56^\circ 9')}$$

$$\frac{R_3}{\cos 56^\circ 9'} = \frac{240.8}{\sin 60^\circ} = \frac{R_4 - 600}{\sin 26^\circ 9'}$$

$$\therefore \quad R_3 = \frac{240.8 \times \cos 56^\circ 9'}{\sin 60^\circ}$$

$$= \frac{240.8 \times 0.5571}{0.866} = \mathbf{154.9\ N}$$ A

$$\text{and} \quad R_4 - 600 = \frac{240.8 \times \sin 26^\circ 9'}{\sin 60^\circ}$$

$$= \frac{240.8 \times 0.4407}{0.866} = 122.5 \text{ N}$$

$$\text{or} \quad R_4 = 122.5 + 600 = \mathbf{722.5\ N}$$ A

Prob.9. Two cylinders of diameters 100 mm and 50 mm, weighing N and 50 N respectively are placed in a trough as shown in fig. 4. Neglecting friction, find the reactions at point of contacts 1, 2, 3 and 4

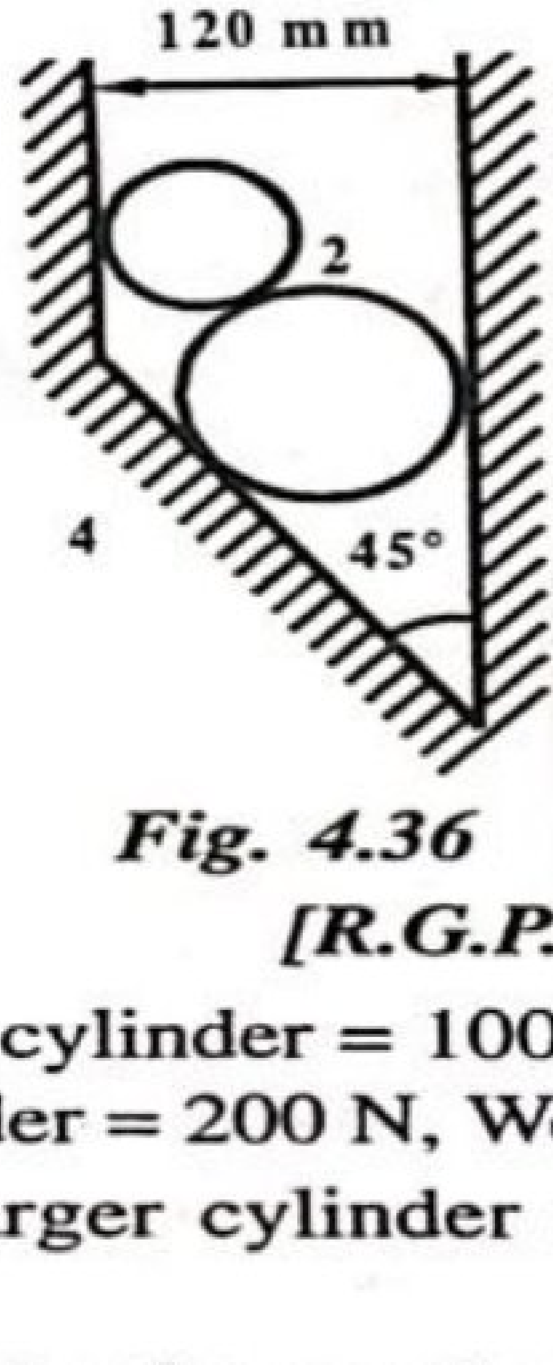


Fig. 4.36

[R.G.P.V., Dec. 2003, June 2008

Sol. Given, Dia. of larger cylinder = 100 mm, Dia. of smaller cylind 50 mm, Weight of larger cylinder = 200 N, Weight of smaller cylinder = 5

Let E be the centre of larger cylinder and F be the centre of sma cylinder.

Also let R_1, R_2, R_3 and R_4 be the reactions at points of contact 1, 2, 3 4 respectively.

Fig. 4.36 is reproduced in fig. 4.37 to determine the direction of reaction R_2. From geometry of fig. 4.37, we have

$$EF = \text{Radius of larger cylinder} + \text{Radius of smaller cylinder}$$
$$= 50 + 25 = 75 \text{ mm}$$

and

$$DE = HI = GJ - GH - IJ$$
$$= 120 - 25 - 50$$
$$= 45 \text{ mm}$$

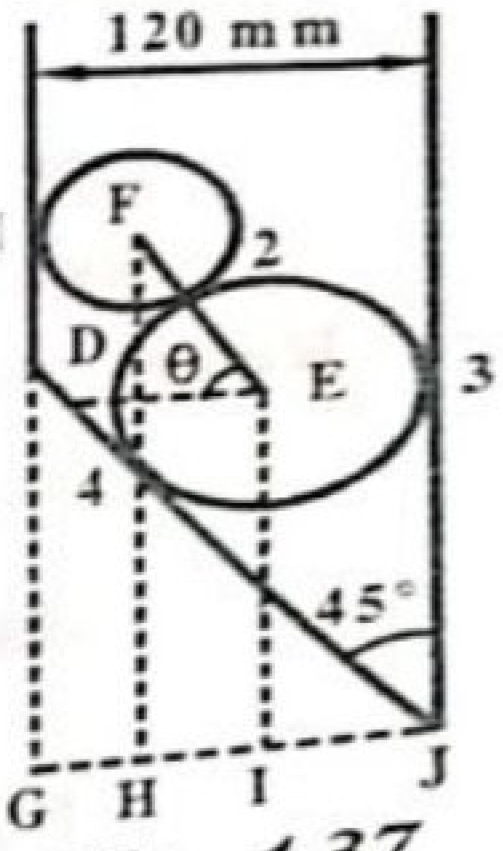


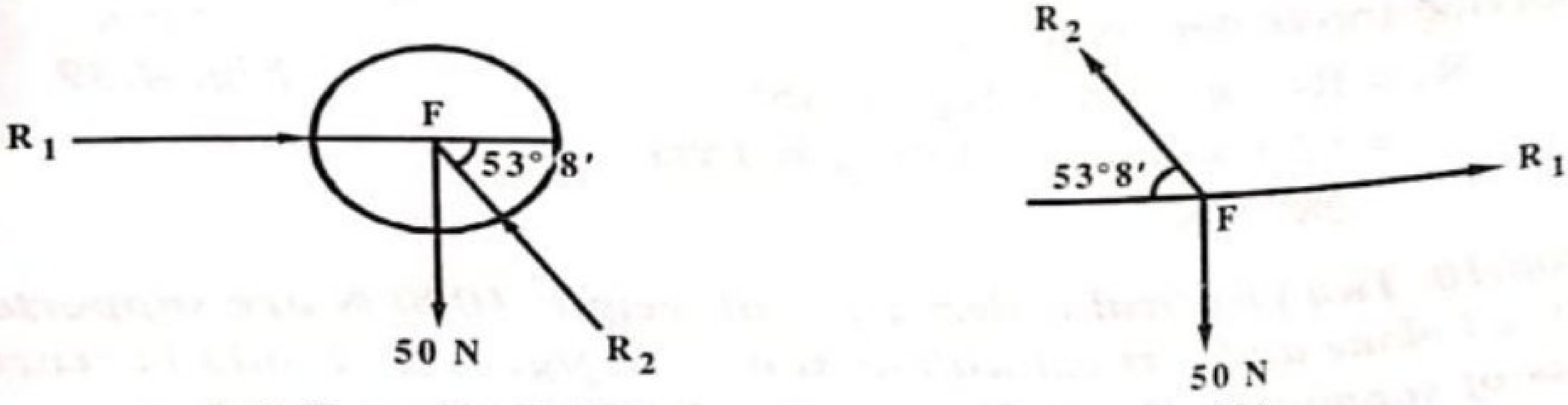
Fig. 4.37

Now from Δ DEF

$$\cos\theta = \frac{DE}{EF} = \frac{45}{75} = 0.6$$

$$\therefore \quad \theta = \cos^{-1}(0.6) = 53°8'$$

Considering the equilibrium of smaller cylinder. It is in equilibrium under the action of three forces as shown in fig. 4.38 (a) and are as follows –



(a) Free Body Diagram *(b)*

Fig. 4.38

(i) Weight 50 N of cylinder acting vertically downwards.

(ii) Reaction R_1 at point 1, acting horizontally.

(iii) Reaction R_2 at point 2, acting at an angle of 53°8'.

Force system acting at point F is shown in fig. 4.38 (b).

Applying Lami's equation at F,

$$\frac{50}{\sin(180°-53°8')} = \frac{R_1}{\sin(90°+53°8')} = \frac{R_2}{\sin 90°}$$

$$\frac{50}{\sin 53°8'} = \frac{R_1}{\cos 53°8'} = \frac{R_2}{1}$$

$$\therefore \quad R_1 = \frac{50}{\sin 53°8'} \times \cos 53°8' = \frac{50}{\tan 53°8'} = \mathbf{37.5\ N} \quad \textbf{Ans.}$$

and

$$R_2 = \frac{50}{\sin 53°8'} = \mathbf{62.5\ N} \quad \textbf{Ans.}$$

Now considering the equilibrium of larger cylinder. It is in equilibri under the action of four forces as shown in fig. 4.39 and are as follows –

(i) Weight 200 N of cylinder acting vertically downwards.
(ii) Reaction R_2 at point 2, at an angle of 53°8'.
(iii) Reaction R_4 at point 4, normal to inclined surface.
(iv) Reaction R_3 at point 3, acting horizontally.

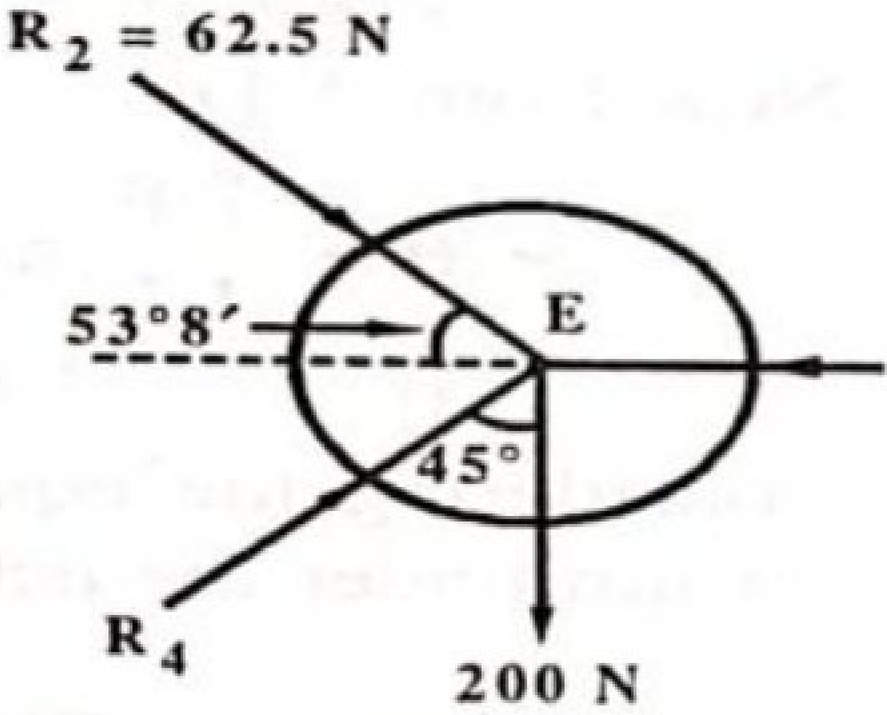


Fig. 4.39

Resolving forces vertically,

$$R_4 \cos 45° = R_2 \sin 53°8' + 200$$

$$R_4 \times \frac{1}{\sqrt{2}} = 62.5 \times 0.8 + 200$$

$$\therefore \quad R_4 = 250 \times \sqrt{2}$$

$$= \mathbf{353.55\ N} \qquad \textbf{Ans.}$$

and resolving forces horizontally,

$$R_3 = R_2 \cos 53°8' + R_4 \sin 45°$$

$$= 62.5 \times 0.6 + 353.55 \times 0.7071$$

$$= \mathbf{287.5\ N}$$

A

Prob.10. Two identical rollers each of weight 1000 N are supported an inclined plane and vertical wall as shown in fig. 4.40. Find the reactio at points of support A, B and C. Assume all surfaces are smooth.

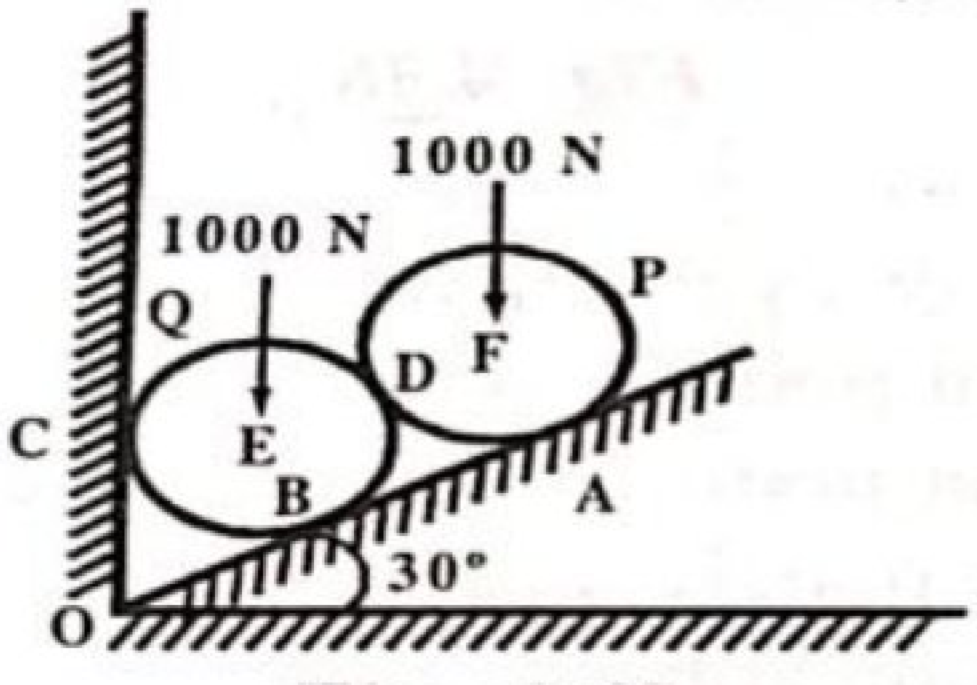


Fig. 4.40

(R.G.P.V., Sept. 200

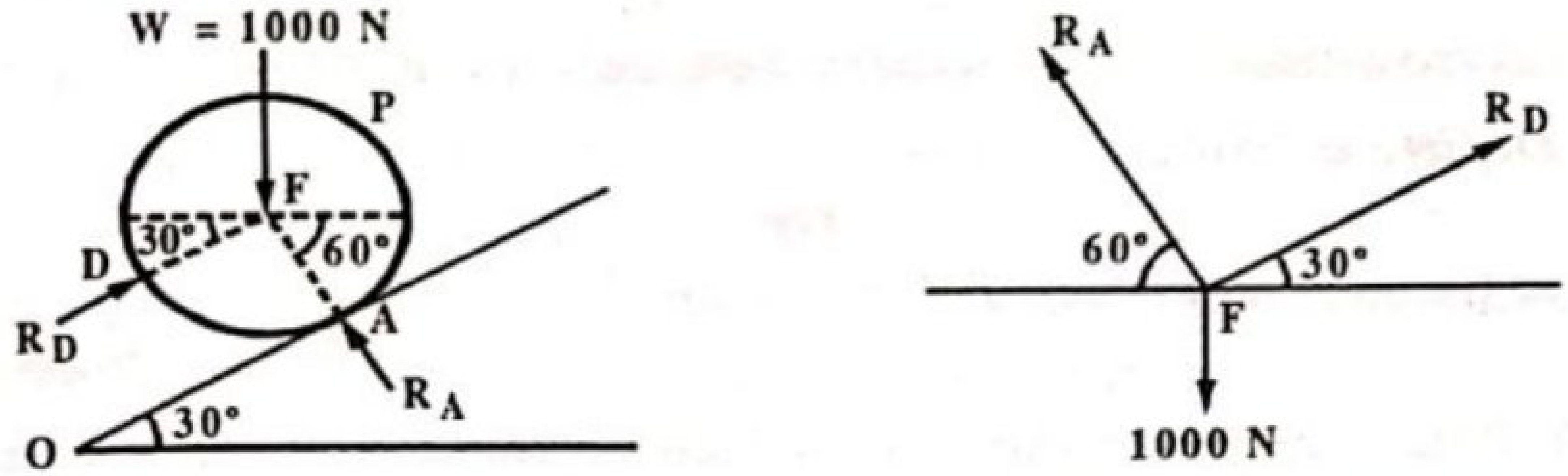
Sol. Given, weight of each roller = 1000 N.

As both the rollers are identical so they will exert an identical reaction each other. Let this reaction be R_D. Reactions at supports A, B and C can assumed R_A, R_B and R_C respectively.

Now consider the equilibrium of the roller P, first. It is in equilibriu under the action of following forces –

(i) Weight 1000 N acting vertically downwards.
(ii) Reaction R_D at point D, parallel to OA.
(iii) Reaction R_A at point A, normal to OA.

Free body diagram of roller P is shown in fig. 4.41 (a) and system of forces acting at its centre F is shown in fig. 4.41 (b).



(a) Free Body Diagram *(b) Space Diagram*

Fig. 4.41

Applying Lami's equation at F,

$$\frac{1000}{\sin 90^\circ} = \frac{R_A}{\sin 120^\circ} = \frac{R_D}{\sin 150^\circ}$$

$$\therefore \quad R_A = \frac{1000}{\sin 90^\circ} \times \sin 120^\circ = \mathbf{866\ N}$$ **Ans.**

and

$$R_D = \frac{1000}{\sin 90^\circ} \times \sin 150^\circ = 500\ \text{N}$$

Now considering equilibrium of roller Q (Fig. 4.42). It is in equilibrium under the action of following forces –

(i) Weight 1000 N acting vertically downwards.
(ii) Reaction R_D at point D, parallel to OB.
(iii) Reaction R_B at point B, normal to OB.
(iv) Reaction R_C acting horizontally.

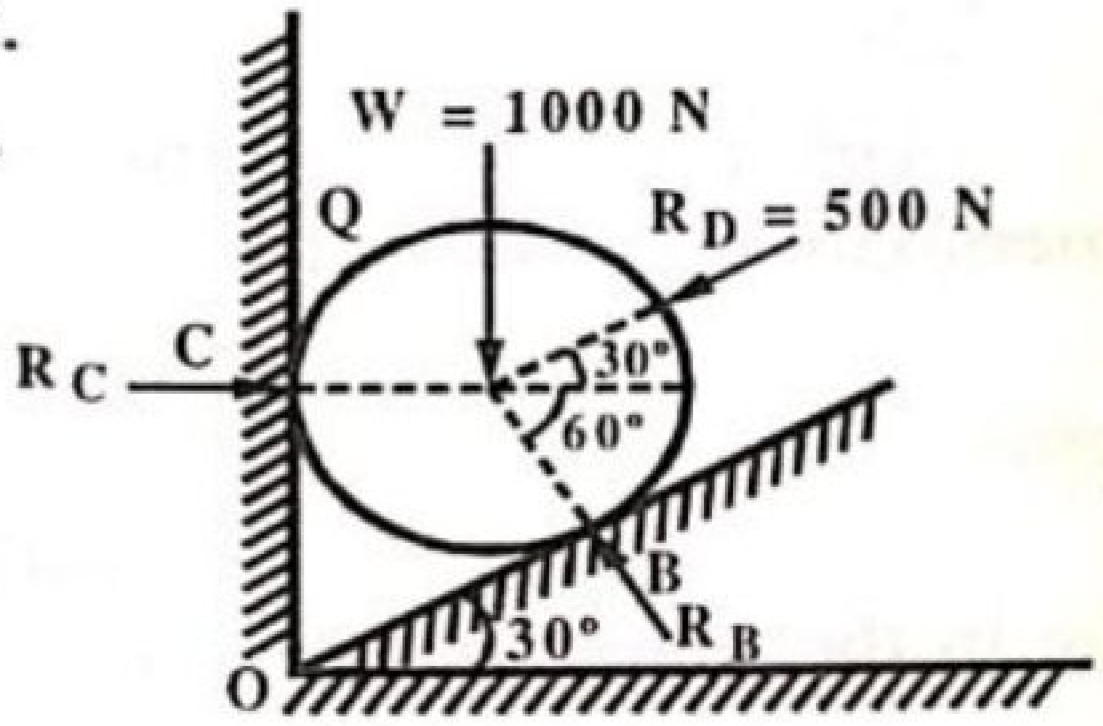


Fig. 4.42

Resolving forces vertically, we get

$$1000 + R_D \sin 30^\circ = R_B \sin 60^\circ$$

$$1000 + 500 \times \frac{1}{2} = R_B \times \frac{\sqrt{3}}{2}$$

$$\therefore \quad R_B = \frac{1250}{\frac{\sqrt{3}}{2}}$$

$$= \mathbf{1443.37\ N}$$ **Ans.**

Now resolving the forces horizontally, we get

$$R_C = R_D \cos 30^\circ + R_B \cos 60^\circ$$

$$= 500 \times \frac{\sqrt{3}}{2} + 1443.37 \times \frac{1}{2}$$

$$= \mathbf{1154.7\ N}$$ **Ans.**

ANALYSIS OF PLANE TRUSSES – METHOD OF JOINTS, METHOD OF SECTIONS

Q.37. Define a truss.

Or

What is framed structure ? List its applications.

[R.G.P.V., June 2008(N)

Ans. A ***truss*** may be defined as a structure made up of several bars joine together at their ends. These bars which are made up of angles or chann sections are called ***members*** of the truss. Various members of a truss ar joined together by riveting, welding or by nuts and bolts. However, fo calculation purpose, joints are assumed to be hinged or pin-jointed. A truss i a rigid structure, which provides great strength over large span of structur Thus, it is more practical and economical, than other solid types of structur A truss is mainly used for supporting roofs of buildings, television towe antennas, bridges, etc.

A truss is also called as a frame or framed structure.

Q.38. What are the assumptions made while analysing a frame ?

(R.G.P.V., Dec. 2014

Or

State the assumptions made in analysis of perfect plane trusses.

(R.G.P.V., Dec. 2005, Feb. 2010

Ans. Following assumptions are made, while calculating forces in variou members of a plane truss –

(i) All members of a truss are connected at the joints by frictionles pins.

(ii) Trusses are only loaded at the joints and line of action of load lie in the plane of the truss.

(iii) All members of the truss lie in a common plane, i.e. plane truss

(iv) The weight of the members is regarded negligible as compare to other external forces or loads acting on truss, unless stated otherwise.

(v) The truss is rigid and does not deform or change its shape du to application of external loads.

Q.39. What is a truss ? Explain the different types of truss. Also giv assumptions made in the analysis of truss. ***(R.G.P.V., June 2011***

Ans. **Truss** – Refer Q.37.

Types of Trusses – Trusses can be classified in various ways as discusse below –

In the broader sense, trusses can be classified as plane truss and space truss. If the centre lines of the members of a truss lie in one plane, the truss is called a ***plane truss***. If these lines do not lie in one plane, as in the case of the shear legs, the truss is called a ***space truss.***

On the basis of their rigidity, trusses can be classified as –

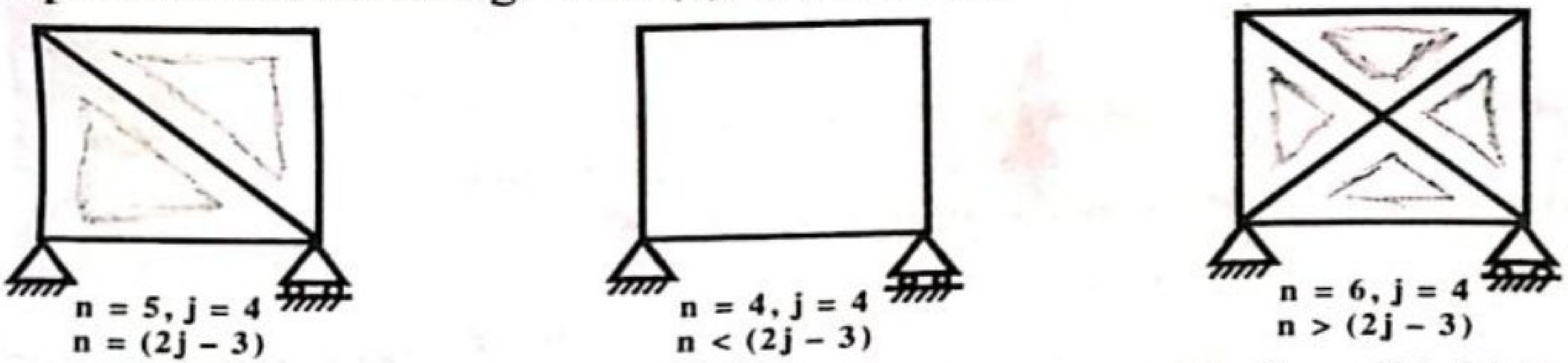
(i) Just rigid (ii) Under rigid (iii) Over rigid.

A ***just rigid*** truss is an idealised term, in which number of members are just sufficient to maintain the structure stable under external loading. If any of its member is removed, its rigidity gets destroyed. A triangle with three members is an elementary just rigid truss. A simple plane truss is built up from a triangle by adding two members at each joint.

A relation between number of joints (j) and number of members (n), for a just rigid truss is given as

$$n = 2j - 3$$

If the number of members are more than $(2j - 3)$, the truss is said to be ***over rigid*** and if, that is less than $(2j - 3)$, the truss is known as ***under rigid.*** Examples are shown in fig. 4.43 (a), (b) and (c).



(a) Just Rigid Truss ***(b) Under Rigid Truss*** ***(c) Over Rigid Truss***

Fig. 4.43

Trusses of frames can also be classified as –

(i) Perfect frame (ii) Imperfect frame.

These types of frames are discussed in Q.40.

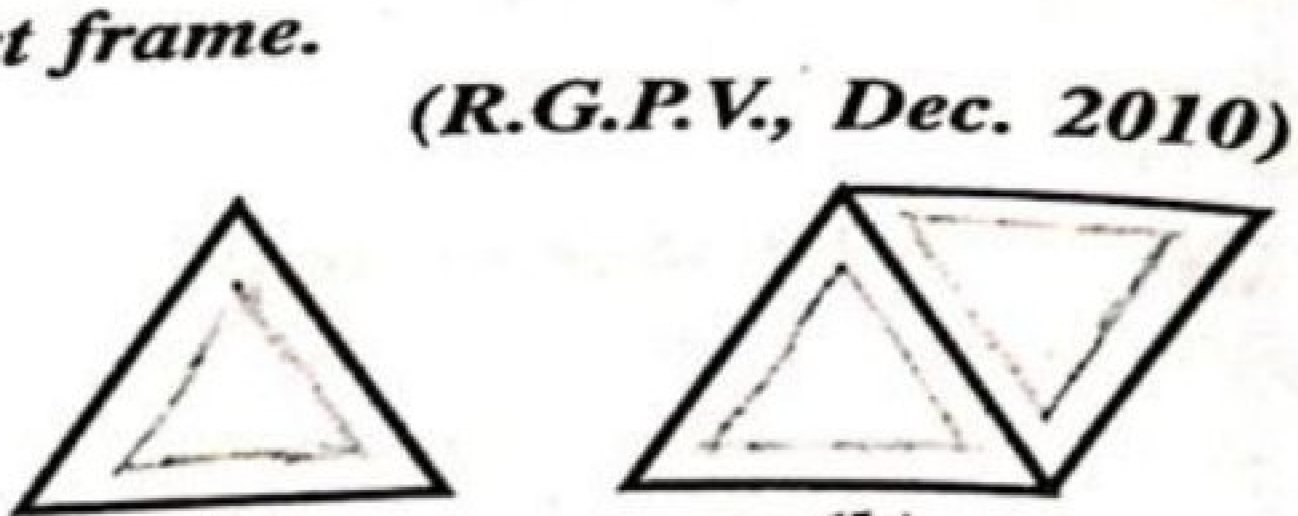
Assumptions – Refer Q.38.

Q.40. Discuss the following –

(i) Perfect frame (ii) Imperfect frame.

(R.G.P.V., Dec. 2010)

Ans. (i) Perfect Frame – A ***perfect frame*** is that, which is made up of members just sufficient to keep it in equilibrium, when loaded, without destroying its shape. A perfect frame is just rigid.



(a) ***(b)***

Fig. 4.44 Perfect Frame

The simplest perfect frame is a triangle, which contains three member and three joints as shown in fig. 4.44 (a). Now, if we want to increase anothe joint we will have to add two more members as shown in fig. 4.44 (b).

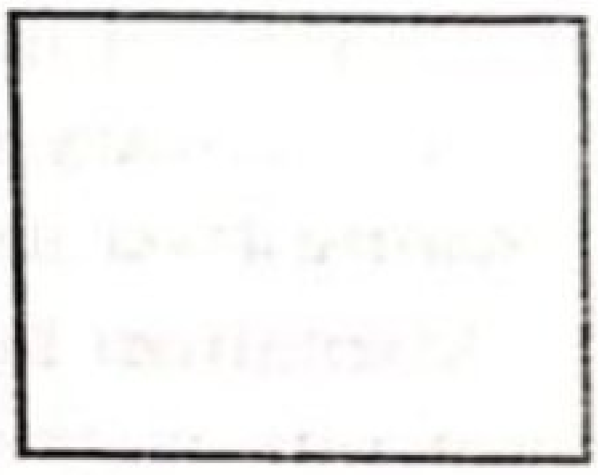
The mathematical relation between number of members (n) and numb of joints (j) for a perfect frame can be given as,

$$n = 2j - 3 \qquad \text{...(i}$$

(ii) Imperfect Frame – A frame which does not satisfy the equatio (i) is known as ***imperfect frame.*** An imperfect frame may be of followin two types –

(a) Deficient frame (b) Redundant frame.

(a) Deficient Frame – It is an imperfect frame, in which the number of members are less than (2j – 3) as shown in fig. 4.45. A deficient frame is under rigid and gets distorted when loaded.

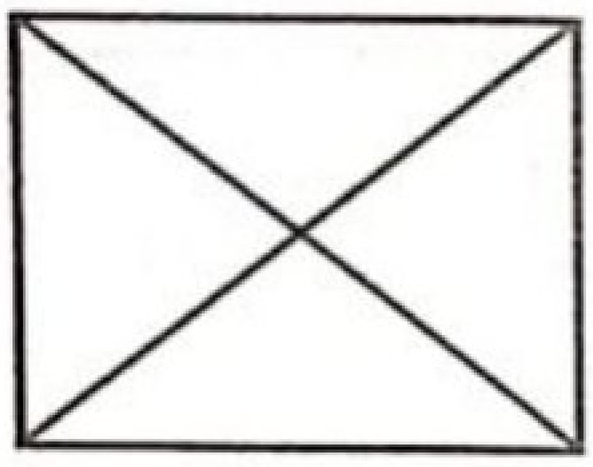


$n = 4, j = 4$
$n < (2j - 3)$

Fig. 4.45 Deficie Frame

(b) Redundant Frame – A frame in which number of joints $n \neq 2j - 3$, where j is the number of joints is known as an imperfect frame.

An imperfect frame in which number of members is more than the (2j – 3) is known as a ***redundant frame***. A redundant frame is over-rigid and forces in its members cannot be determined statically. Fig. 4.46 shows a redundant frame.



$n = 6, j = 4$
$n > (2j - 3)$

Fig. 4.46 Redundan Frame

Q.41. What is redundant frame ?

(R.G.P.V., Dec. 2014)

Ans. Refer Q.40 (ii) (b).

Q.42. What do you mean by perfect, deficient and redundant frames What are the assumptions made in analysis of perfect frames ?

(R.G.P.V., Dec. 201

Ans. Refer Q.40 (i), (ii) and Q.38.

Q.43. How determinacy and stability of a frame can be ascertained

(R.G.P.V., June 201

Ans. A frame/truss is said to be perfect when number of members (n) i a truss are given by

$$n = 2j - 3$$

where j = Number of joints.

Forces in the members of a perfect frame are determined by using law statics, hence they are called statically determinate trusses.

Frames for which, n > (2j – 3) are called redundant or statically indetermina frames, while frames for which n < (2j – 3) are called deficient frames. The frames are not stable and get distorted when loaded. Thus, necessary and sufficient condition for a frame to be statically determinate and stable is

$$n = 2j - 3$$

Q.44. What are the different methods of analysis of a perfect frame ? Which one is used where ? Why ? ***(R.G.P.V., June 2015)***

Ans. A perfect frame can be analysed by following two methods –

(i) Analytical methods (ii) Graphical method.

Analytical methods are of two types –

(a) Method of joints (b) Method of sections.

Method of joints is used when forces in all the members of a truss need to be determined. In this method all joints are analyzed one-by-one. This method gives accurate results but become tedious when number of joints are more.

Method of sections is used when forces in only a few members are need to be known. This method is based upon the principle of equilibrium of a system. In this method, members in which forces have to be determined need to be considered only. However, it is a complex method.

Graphical method of frame analysis is used when analytical methods become tedious and are difficult to apply. It is a simple and comparatively fool proof method, which gives reasonably accurate results in a quick time.

Q.45. Explain the method of joints. ***(R.G.P.V., Dec. 2016)***

Ans. In joints method of truss analysis, first reactions at the supports are determined and then, each and every joint is treated as a free body in equilibrium. The forces in various members can be determined by applying conditions of equilibrium, i.e. $\Sigma V = 0$, and $\Sigma H = 0$, or by applying Lami's theorem. The joint should be selected in such a way that at any time, it should not contain more than two members, in which forces are unknown.

(a) Member Under Tension *(b) Member Under Compression*

Fig. 4.47

The force in the member will be compressive, if the member pushes the joint to which it is connected, while the force in the member will be tensile, if the member pulls the joint to which it is connected. The arrows are marked on the members to show their effect on joints. If a member AB is under tension the arrows are directed away from A and B as shown in fig. 4.47 (a). When AB is under compression the arrows are directed towards A and B as shown in fig. 4.47 (b).

Method of joints is a lengthy method, as all joints need to be analyzed one by one.

Q.46. Explain the method of sections for analysis of forces in th members of a truss. ***(R.G.P.V., Feb. 2007, March/April 2010***

Ans. In method of sections an imaginary section is drawn which divide the truss in two parts. This method is also based upon the principle of equilibriu of a system. If a system is in equilibrium under the application of loads, the any part or section of the system will also be in equilibrium. Section lin should be drawn in such a way that it does not cut more than three member with unknown forces in them. Because there are only three equations o equilibrium ($\Sigma F_x = 0$, $\Sigma F_y = 0$ and $\Sigma M = 0$), from which only three unknown can be determined. After dividing the truss in two parts any one part (left o right) can be analysed by applying conditions of equilibrium, which is i equilibrium under the action of external loads and the forces exerted upon it b the members cut by the section.

This method is particularly useful, when the forces in a few members ar required. This can be done very easily by passing a section line through membe or members in which forces have to be determined, without determining th forces in all the members.

For example consider a simple truss as shown in fig. 4.48, in which forces in the members AB and BC have to be determined. Vertical reactions R_B and R_C can be determined by using equations of equilibrium. In this case since truss is symmetrically loaded, thus reactions will be,

$$R_B = R_C = \frac{2}{2} = 1 \text{ kN}$$

A section line ①-① cutting the members AB and BC had been drawn. Now from the two parts of the truss thus obtained the portion having less number of forces, i.e. left part is selected for analysis. By using the equations of equilibrium, i.e. $\Sigma F_x = \Sigma F_y = 0$ and Σ = 0, the forces in the members AB and BC can be determined.

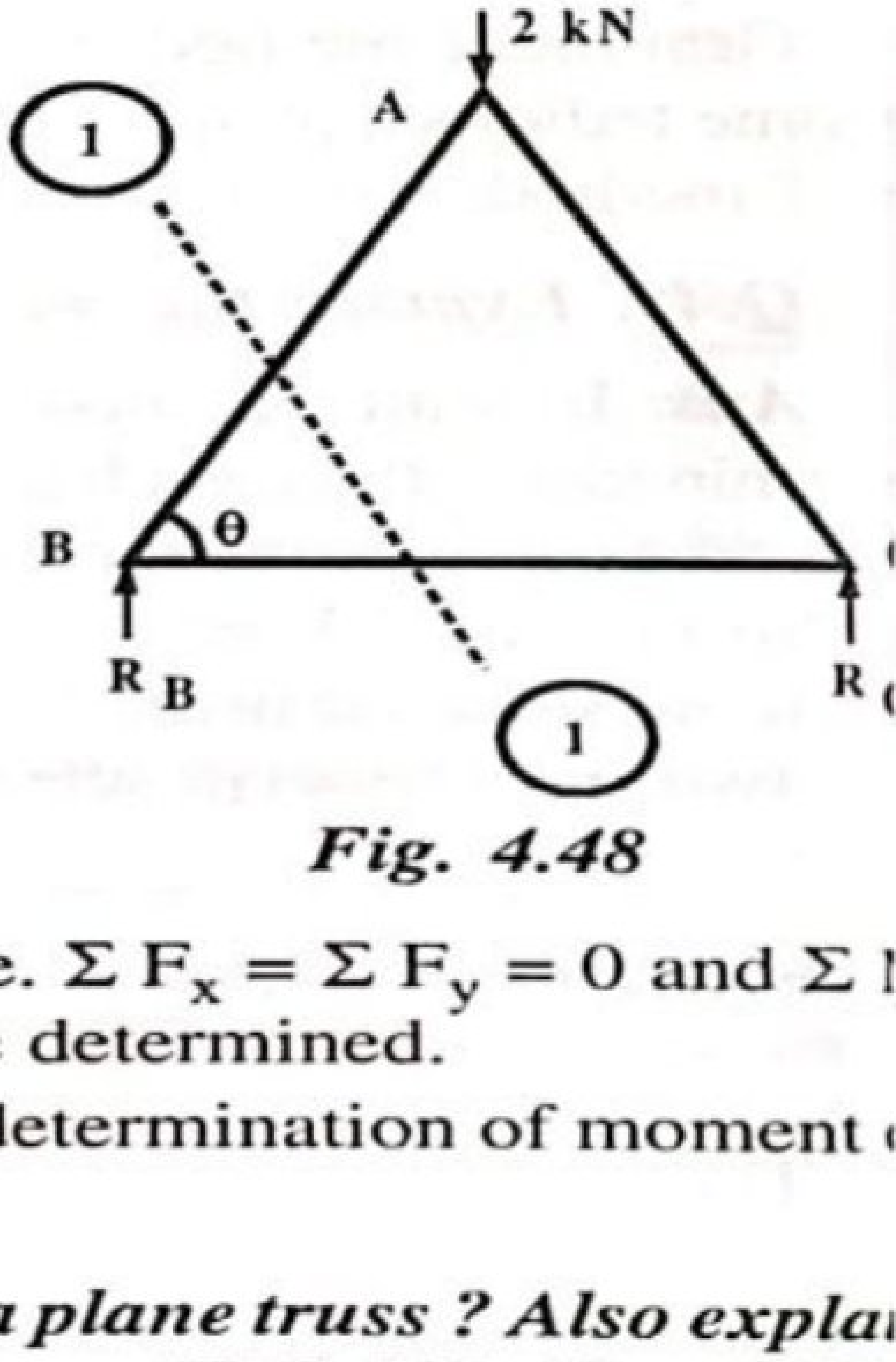


Fig. 4.48

Method of sections is a complex method and determination of moment forces requires careful analysis.

Q.47. What are different methods to analysis a plane truss ? Also expla their limitations. ***(R.G.P.V., Dec. 201***

Ans. Refer Q.44, Q.45 and Q.46.

Q.48. What are various limitations of method of joint and method section ? ***(R.G.P.V., June 201***

Ans. Refer Q.44, Q.45 and Q.46.

Q.49. What do you understand by the term "Trusses" ? Also explain various methods to analyse a truss with their advantages and disadvantages. ***(R.G.P.V., Dec. 2017)***

Ans. Refer Q.37, Q.44, Q.45 and Q.46.

NUMERICAL PROBLEMS

Prob.11. Determine the forces in all the members of the truss loaded and supported as shown in fig. 4.49.

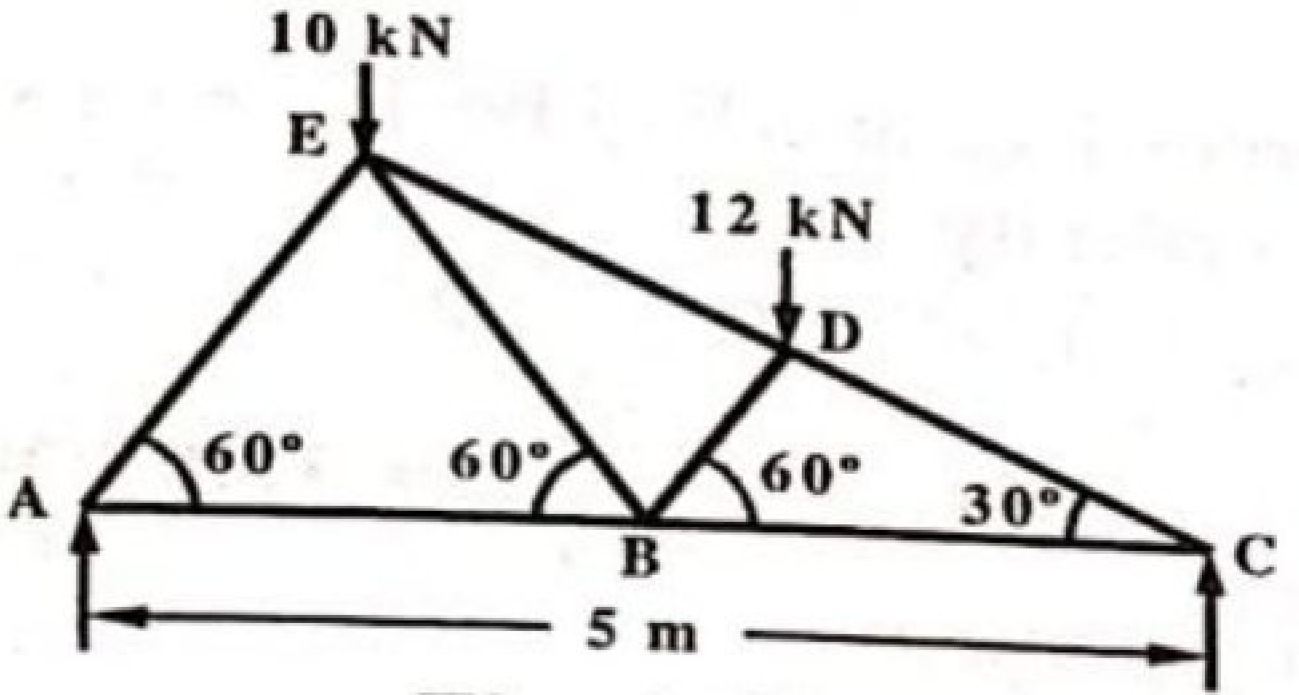


Fig. 4.49 ***(R.G.P.V., Dec. 2008, 2012)***

Sol. Let R_A and R_C be the vertical reactions at supports A and C respectively. Triangle ACE is a right-angled triangle having ∠AEC = 90°.

$$\therefore \quad \frac{AE}{AC} = \cos 60^\circ$$

$$\text{or} \quad AE = AC \cos 60^\circ = 5 \times \frac{1}{2} = 2.5 \text{ m}$$

The distance of line of action of the vertical load of 10 kN at E, from point A

$$= AE \cos 60^\circ = 2.5 \times \frac{1}{2} = 1.25 \text{ m}$$

Now in equilateral ΔABE,

$$AB = AE = 2.5 \text{ m}$$

$$\therefore \quad BC = AC - AB = 5 - 2.5$$

$$= 2.5 \text{ m}$$

Now ΔBDC is also a right-angled triangle having ∠BDC = 90°, thus

$$BD = BC \cos 60^\circ$$

$$= 2.5 \times \frac{1}{2} = 1.25 \text{ m}$$

The distance of line of action of the vertical load of 12 kN at D, from point A

$$= AB + BD \cos 60^\circ$$

$$= 2.5 + 1.25 \times \frac{1}{2} = 3.125 \text{ m}$$

Now taking moments of various loads about support A, we get

$$R_C \times 5 = 10 \times 1.25 + 12 \times 3.125 = 50$$

$$\therefore \quad R_C = \frac{50}{5} = 10 \text{ kN}$$

and

$$\begin{aligned} R_A &= \text{Total vertical load} - R_C \\ &= 10 + 12 - 10 \\ &= 12 \text{ kN} \end{aligned}$$

Now considering equilibrium of various joints one by one.

Joint-A

Let direction of forces F_{AB} and F_{AE} be assumed as shown in fig. 4.50 (a

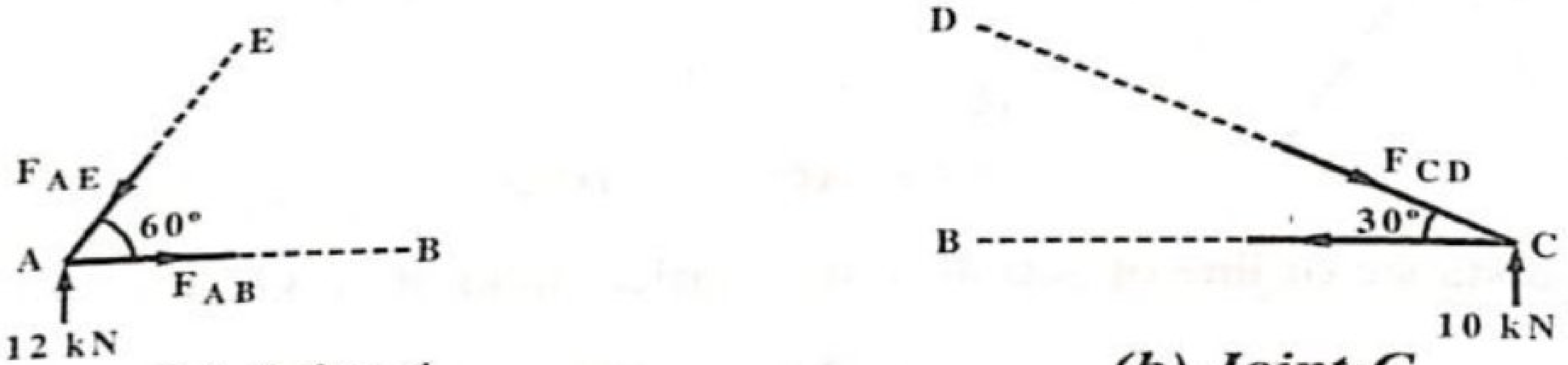
Resolving forces vertically,

$$F_{AE} \sin 60^\circ = R_A = 12$$

$$\therefore \quad F_{AE} = \frac{12}{\sin 60^\circ} = \mathbf{13.8 \text{ kN (compression)}}$$ An

Resolving forces horizontally,

$$\begin{aligned} F_{AB} &= F_{AE} \cos 60^\circ \\ &= 13.8 \times \cos 60^\circ \\ &= \mathbf{6.9 \text{ kN (tension)}} \end{aligned}$$ An



(a) Joint-A *(b) Joint-C*

Fig. 4.50

Joint-C

Let direction of forces F_{BC} and F_{CD} be assumed as shown in fig. 4.50 (t

Resolving forces vertically,

$$F_{CD} \sin 30^\circ = 10$$

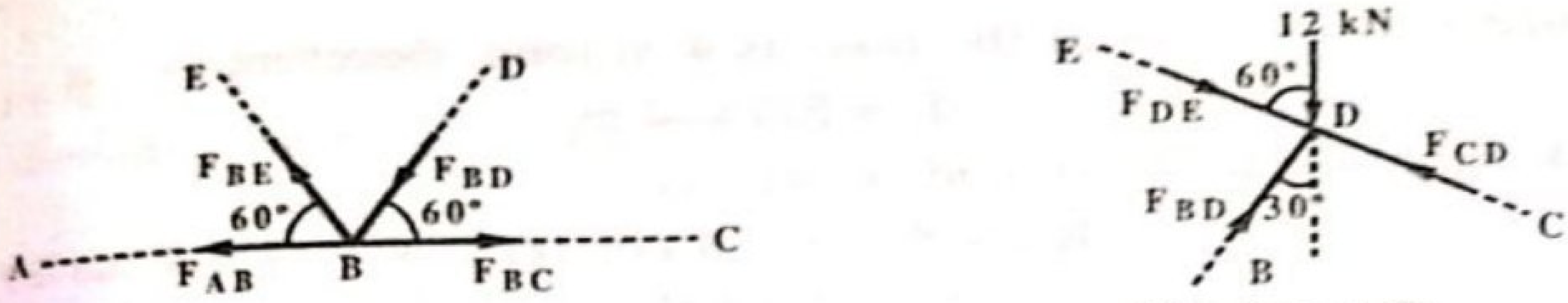
$$\therefore \quad F_{CD} = \frac{10}{\sin 30^\circ} = \mathbf{20 \text{ kN (compression)}}$$ An

Resolving forces horizontally,

$$\begin{aligned} F_{BC} &= F_{CD} \cos 30^\circ \\ &= 20 \times \cos 30^\circ \\ &= \mathbf{17.3 \text{ kN (tension)}} \end{aligned}$$ Ar

Joint-B

Let direction of forces F_{BD} and F_{BE} be assumed as shown in fig. 4.51 (



(a) Joint-B *(b) Joint-D*

Fig. 4.51

Resolving forces vertically,

$$F_{BD} \sin 60° = F_{BE} \sin 60°$$

or

$$F_{BD} = F_{BE}$$

Resolving forces horizontally,

$$F_{AB} + F_{BD} \cos 60° + F_{BE} \cos 60° = F_{BC}$$

$$6.9 + (F_{BD} + F_{BE}) \cos 60° = 17.3$$

$$6.9 + 2F_{BD} \times \frac{1}{2} = 17.3 \qquad (\because F_{BD} = F_{BE})$$

or

$$F_{BD} = 17.3 - 6.9 = \mathbf{10.4\ kN\ (compression)}\ \textbf{Ans.}$$

∴

$$F_{BE} = F_{BD} = \mathbf{10.4\ kN\ (tension)}\ \textbf{Ans.}$$

Joint-D

Let direction of force F_{DE} be assumed as shown in fig. 4.51 (b).

Resolving forces along EDC,

$$F_{DE} + 12 \cos 60° = F_{CD}$$

∴

$$F_{DE} + 12 \times \frac{1}{2} = 20$$

$$F_{DE} = 20 - 6 = \mathbf{14\ kN\ (compression)}\ \textbf{Ans.}$$

Prob.12. The length of each member of the truss shown in fig. 4.52 is 4 m. Loads of 2 kN and 4 kN are applied at joints B and C of the truss. Determine the magnitude and nature of forces in all members of the truss. Both ends are simply supported.

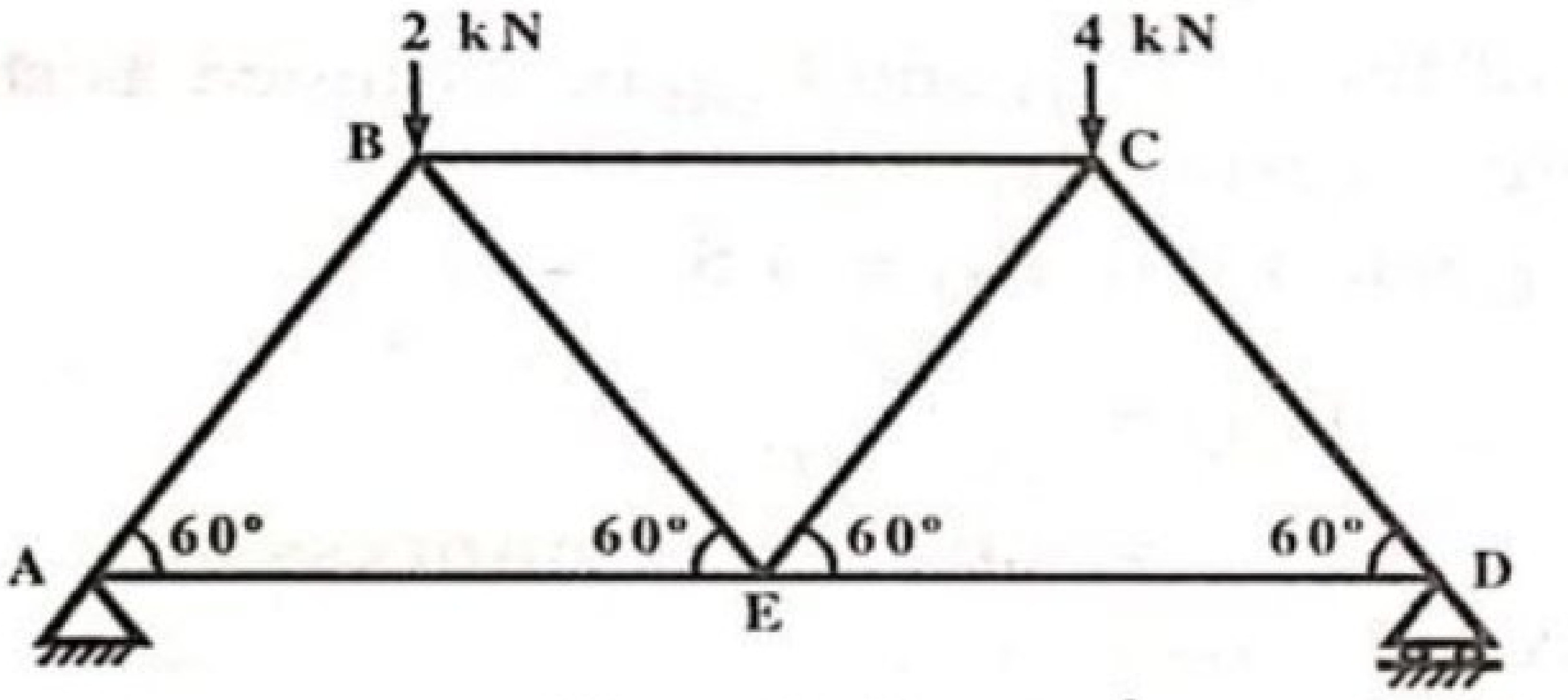


Fig. 4.52 *(R.G.P.V., Dec. 2013)*

Sol. Let R_A and R_D be the vertical reactions at supports A and D respectively.

Since each member of the truss is 4 m long, therefore

$$AE = ED = 4 \text{ m}$$

Taking moments about end A, we get

$$R_D \times 8 = 2 \times 4 \cos 60° + 4 \times (4 + 4 \cos 60°) =$$

$$\therefore \quad R_D = 3.5 \text{ kN}$$

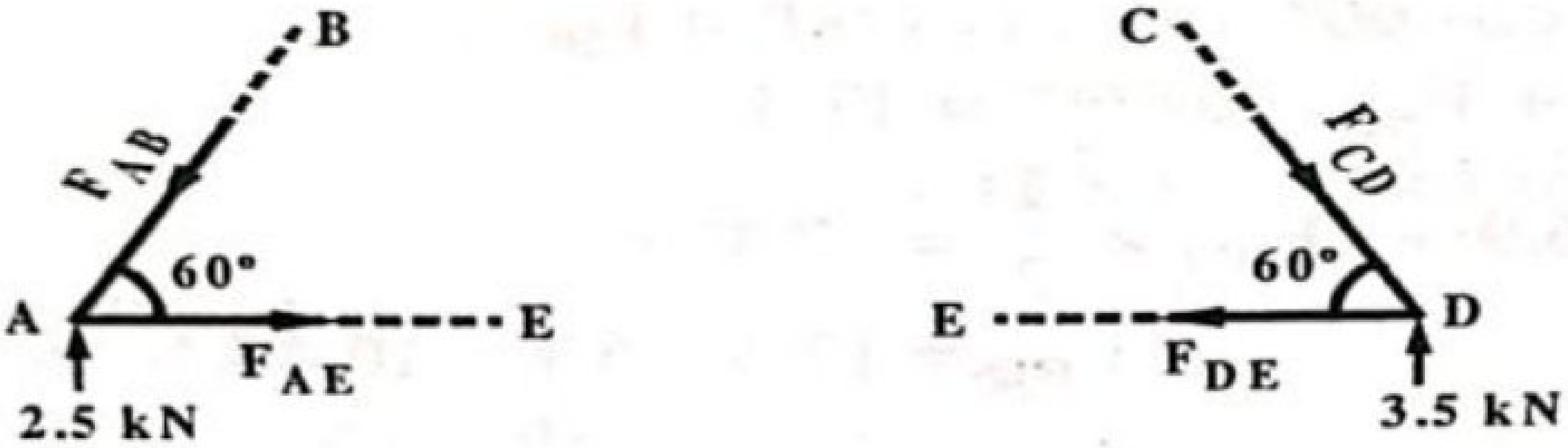
and

$$R_A = \text{Total vertical load} - R_D$$
$$= (2 + 4) - 3.5 = 2.5 \text{ kN}$$

Now considering equilibrium of various joints one by one.

Joint-A

Let direction of forces F_{AB} and F_{AE} be assumed as shown in fig. 4.53



(a) Joint-A *(b) Joint-D*

Fig. 4.53

Resolving forces vertically,

$$F_{AB} \sin 60° = R_A = 2.5$$

$$F_{AB} = \frac{2.5}{\sin 60°}$$

$$= \mathbf{2.88 \text{ kN (compression)}}$$ A

Resolving forces horizontally,

$$F_{AE} = F_{AB} \cos 60°$$
$$= 2.88 \times \cos 60°$$
$$= \mathbf{1.44 \text{ kN (tension)}}$$ A

Joint-D

Let direction of forces F_{CD} and F_{DE} be assumed as shown in fig. 4.53 (

Resolving forces vertically,

$$F_{CD} \sin 60° = R_D = 3.5$$

$$\therefore \quad F_{CD} = \frac{3.5}{\sin 60°}$$

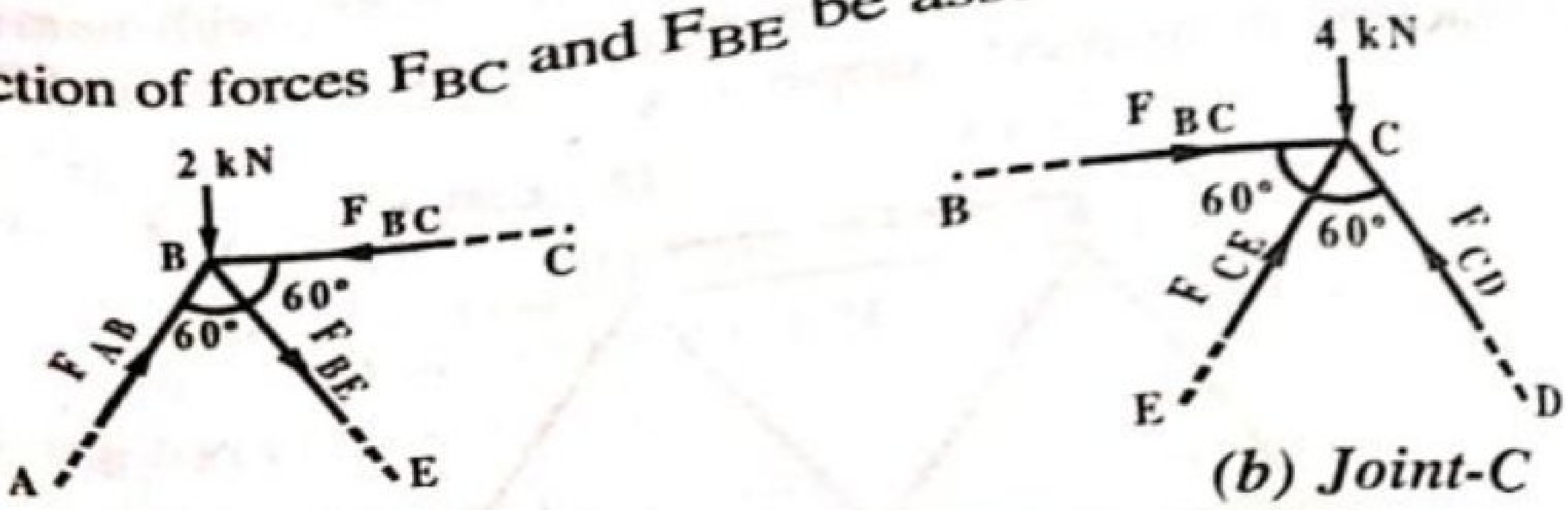
$$= \mathbf{4.04 \text{ kN (compression)}}$$ A

Resolving forces horizontally,

$$F_{DE} = F_{CD} \cos 60°$$
$$= 4.04 \times \cos 60° = \mathbf{2.02 \text{ kN (tension)}}$$ A

Joint-B

Let direction of forces F_{BC} and F_{BE} be assumed as shown in fig. 4.54 (a).



(a) Joint-B

(b) Joint-C

Fig. 4.54

Resolving forces vertically,

$$F_{AB} \sin 60^\circ = F_{BE} \sin 60^\circ + 2$$

$$2.88 \times \sin 60^\circ = F_{BE} \sin 60^\circ + 2$$

$$2.5 - 2 = F_{BE} \sin 60^\circ$$

$$\therefore \quad F_{BE} = \frac{0.5}{\sin 60^\circ} = \mathbf{0.577\ kN\ (tension)} \qquad \text{Ans.}$$

Resolving forces horizontally,

$$F_{BC} = F_{AB} \cos 60^\circ + F_{BE} \cos 60^\circ$$

$$= 2.88 \times \cos 60^\circ + 0.577 \times \cos 60^\circ$$

$$= \mathbf{1.729\ kN\ (compression)} \qquad \text{Ans.}$$

Joint-C

Let direction of force F_{CE} be assumed as shown in fig. 4.54 (b).

Resolving forces vertically,

$$F_{CD} \sin 60^\circ + F_{CE} \sin 60^\circ = 4$$

$$4.04 \sin 60^\circ + F_{CE} \sin 60^\circ = 4$$

$$F_{CE} = \frac{4 - 3.5}{\sin 60^\circ} = \mathbf{0.577\ kN\ (compression)} \qquad \text{Ans.}$$

Prob.13. Analyze the truss shown below in fig. 4.55. All the members are of equal length of 4 m.

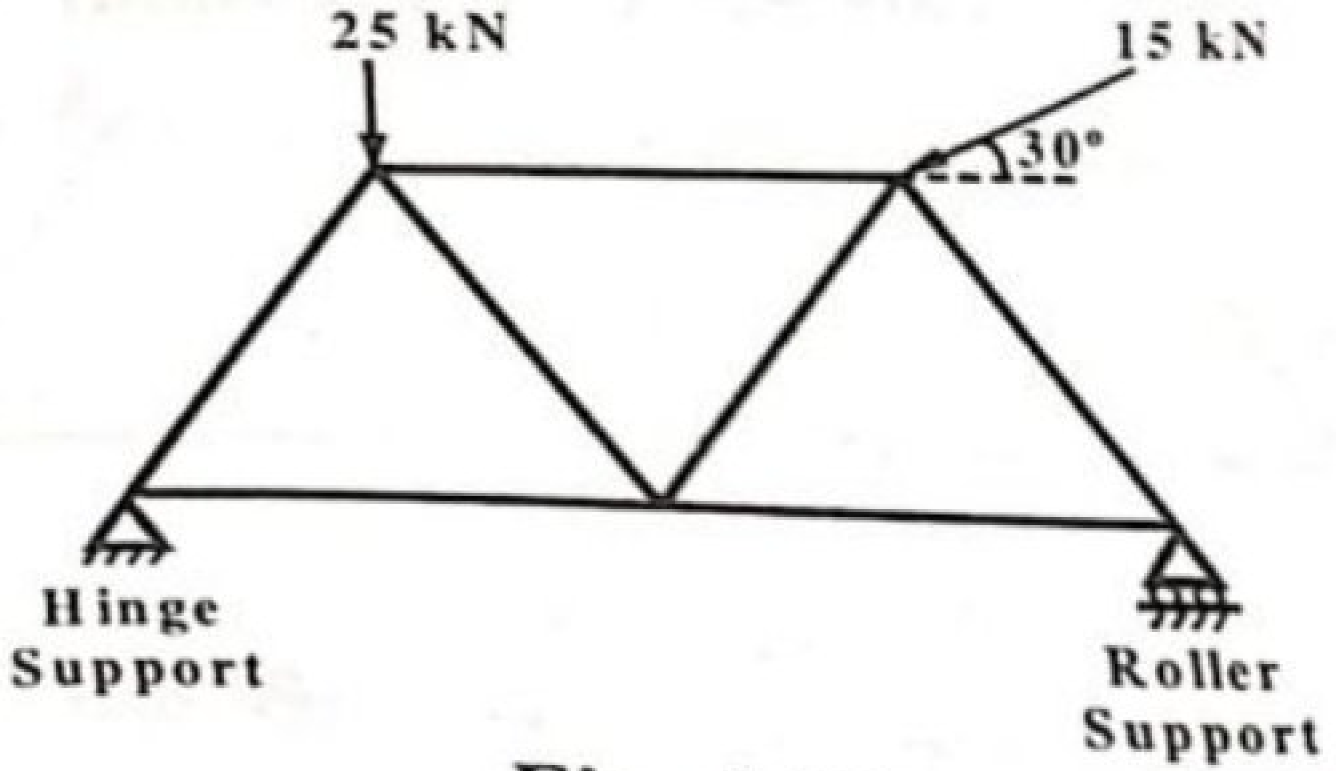


Fig. 4.55

(R.G.P.V., June 2016)

Sol. The given truss is reproduced in fig. 4.56, with name of vari joints. Let R_A and R_B be the vertical reactions at supports A and B, and H_A the horizontal reaction at hinged support A.

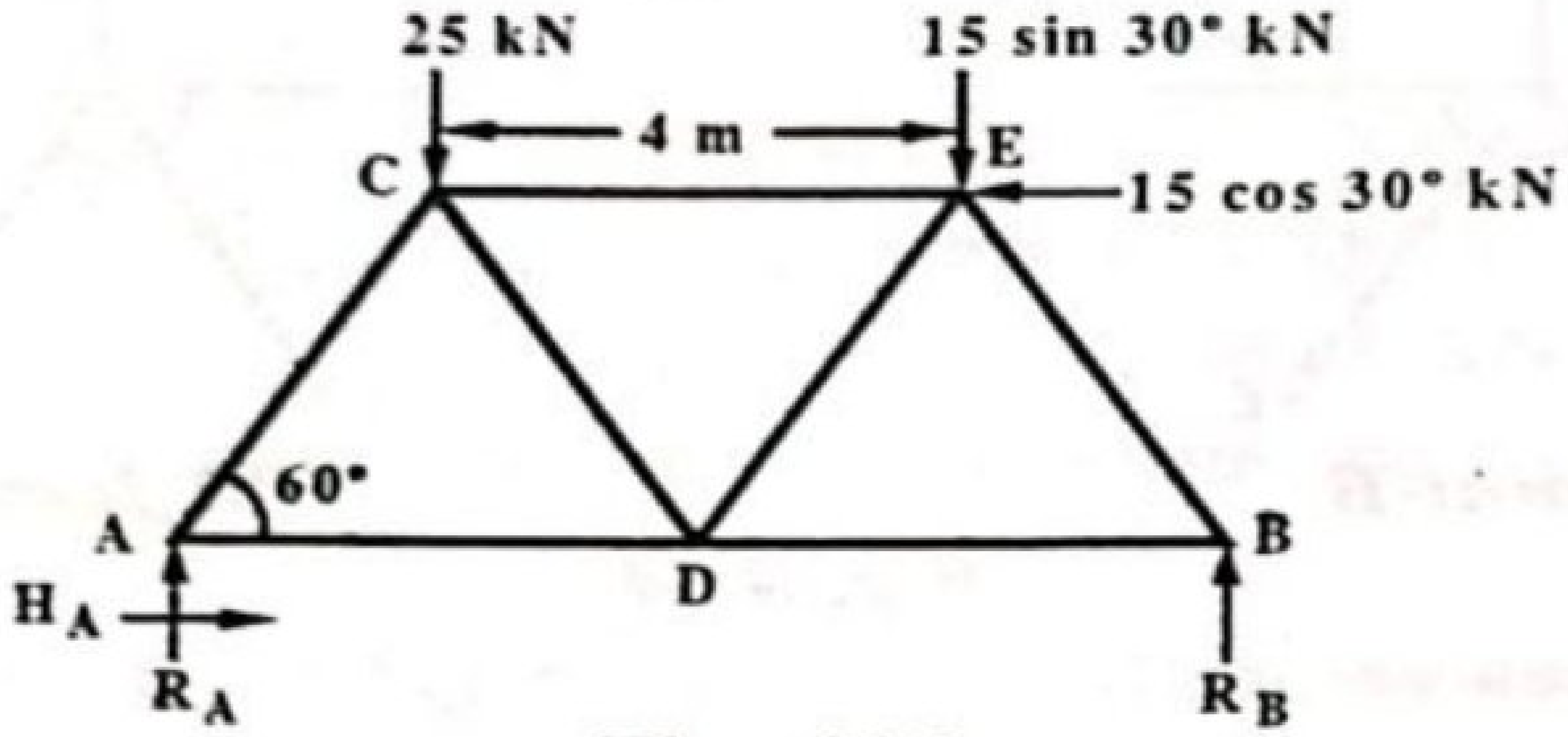


Fig. 4.56

Taking moments about support A, we get

$$R_B \times 8 = 25 \times (4 \cos 60°) + (15 \sin 30°) \times [4 + (4 \cos 60°)]$$

$$R_B \times 8 = 50 + 7.5 \times 6 = 95$$

$$\therefore \quad R_B = 11.875 \text{ kN}$$

and $\quad R_A = \text{Total vertical load} - R_B$

$$= 25 + (15 \sin 30°) - 11.875 = 20.625 \text{ kN}$$

Horizontal reaction at A, i.e. H_A will be equal and opposite to the to horizontal load, thus

$$H_A = 15 \cos 30° = 13 \text{ kN } (\rightarrow)$$

Now considering equilibrium of various joints one by one.

Joint-A

Let direction of forces F_{AC} and F_{AD} be assumed as shown in fig. 4.57 (

Resolving forces vertically,

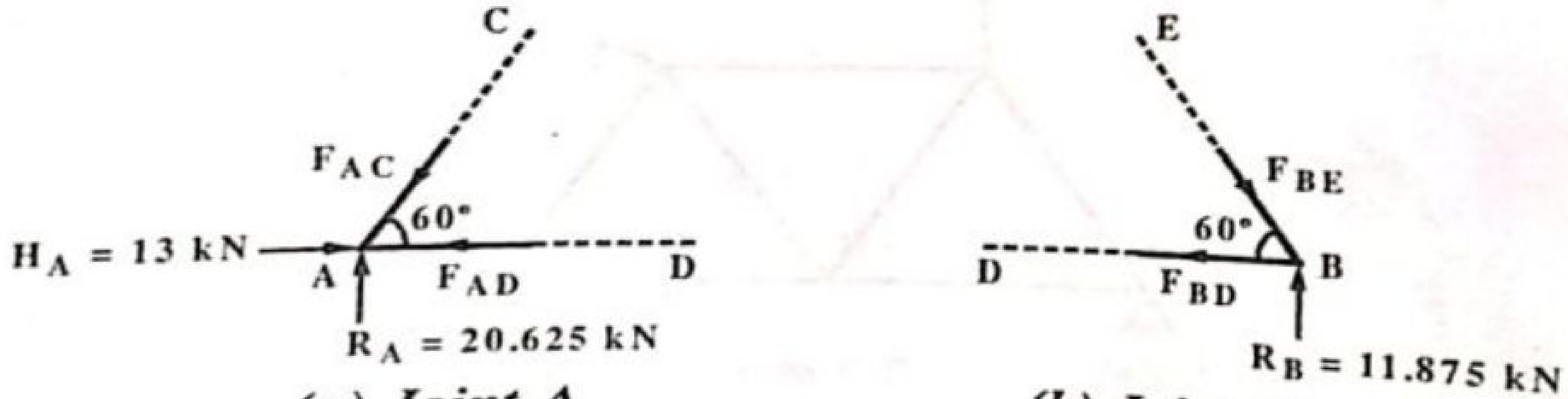
$$F_{AC} \sin 60° = R_A = 20.625$$

$\therefore \quad F_{AC} =$ **23.82 kN (compression)** Ar

Resolving forces horizontally,

$$F_{AD} = H_A - F_{AC} \cos 60° = 13 - 23.82 \cos 60°$$

$=$ **1.09 kN (compression)** Ar



(*a*) *Joint-A* (*b*) *Joint-B*

Fig. 4.57

Joint-B

Let direction of forces F_{BE} and F_{BD} be assumed as shown in fig. 4.57 (b).

Resolving forces vertically,

$$F_{BE} \sin 60^\circ = R_B$$
$$= 11.875$$

$\therefore$ $F_{BE} =$ **13.71 kN (compression)** **Ans.**

Resolving forces horizontally,

$$F_{BD} = F_{BE} \cos 60^\circ$$
$$= 13.71 \cos 60^\circ$$

$=$ **6.855 kN (tension)** **Ans.**

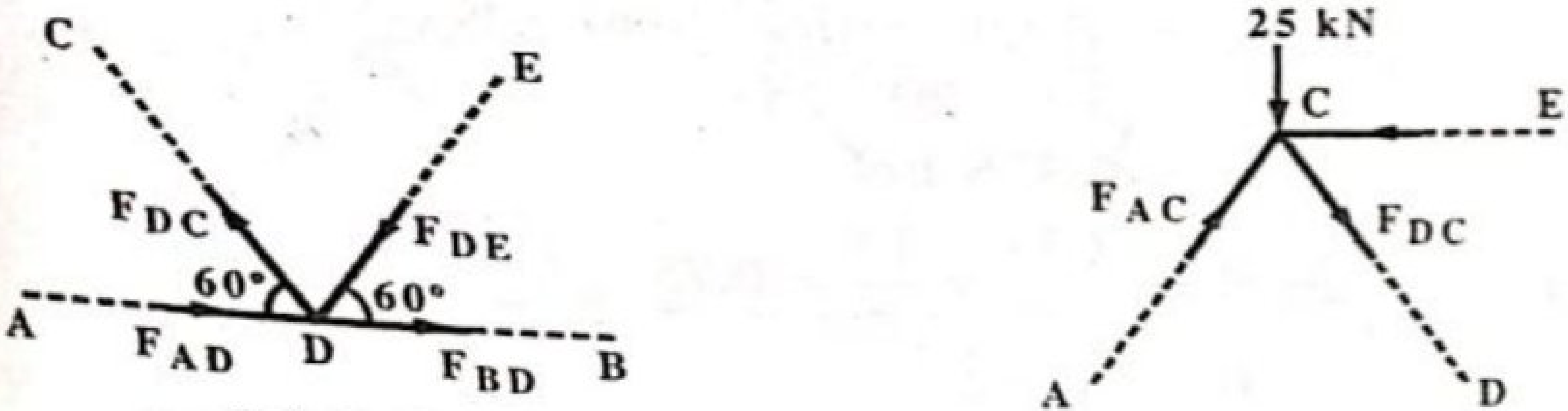
Joint-D

Let direction of forces F_{DC} and F_{DE} be assumed as shown in fig. 4.58 (a)

Resolving forces vertically,

$$F_{DC} \sin 60^\circ = F_{DE} \sin 60^\circ$$

or $$F_{DC} = F_{DE} \qquad \text{...(i)}$$



(a) Joint-D *(b) Joint-C*

Fig. 4.58

Resolving forces horizontally,

$$F_{DC} \cos 60^\circ + F_{DE} \cos 60^\circ = F_{AD} + F_{BD}$$

or $$2\,F_{DC} \cos 60^\circ = 1.09 + 6.855 \qquad (\because F_{DC} = F_{DE})$$

$\therefore$ $F_{DC} =$ **7.945 kN (tension)** **Ans.**

and $F_{DE} =$ **7.945 kN (compression)** **Ans.**

Joint-C

Let direction of force F_{CE} be assumed as shown in fig. 4.58 (b)

Resolving forces horizontally,

$$F_{CE} = F_{AC} \cos 60^\circ + F_{DC} \cos 60^\circ$$
$$= 23.82 \cos 60^\circ + 7.945 \cos 60^\circ$$

$=$ **15.88 kN (compression)** **Ans.**

Prob.14. Determine the magnitude and nature of various forces in the various members of the triangular truss loaded and supported as shown in fig. 4.59.

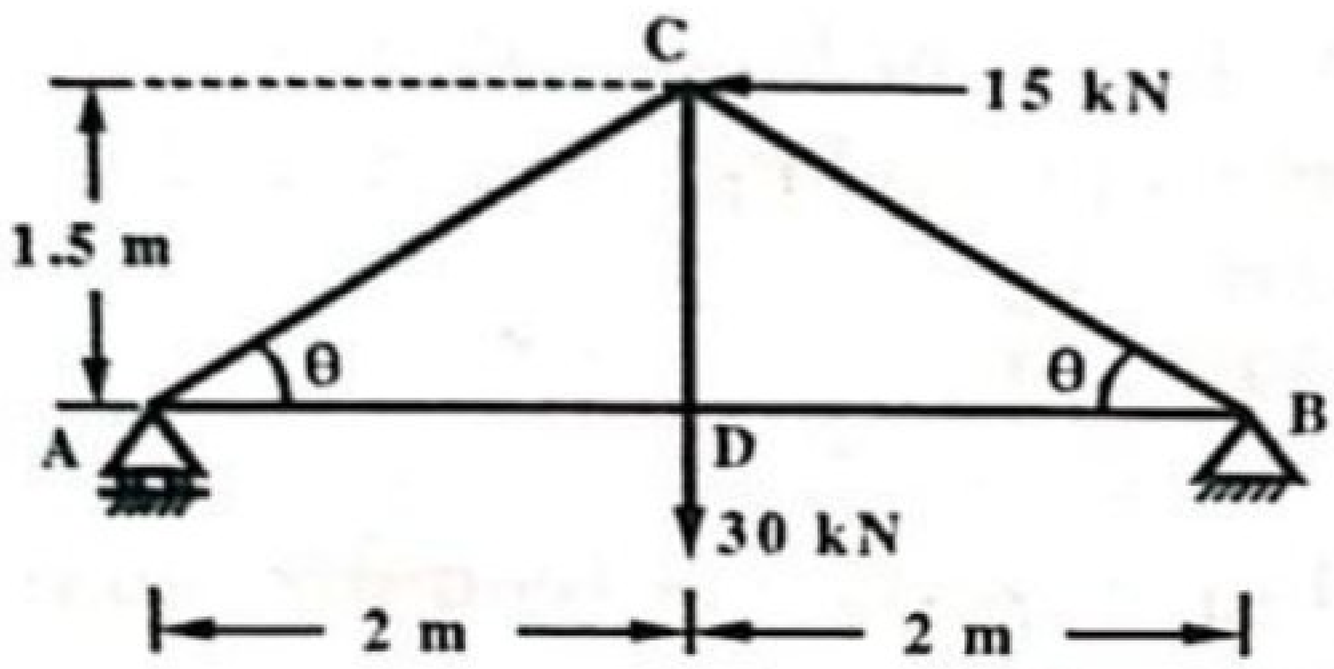


Fig. 4.59 *(R.G.P.V., Dec. 2014*

Sol. Let R_A and R_B be the vertical reactions at supports A and respectively. Since there is roller support at A, there will be only vertical reaction At hinged support B, there also will be a horizontal reaction H_B, which will equal and opposite to the total horizontal load, i.e.

$$H_B = 15 \text{ kN } (\rightarrow)$$

Taking moments about support B, we have

$$R_A \times 4 = (15 \times 1.5) + (30 \times 2) = 82.5$$

$$\therefore \quad R_A = 20.625 \text{ kN}$$

and

$$R_B = \text{Total vertical load} - R_A$$
$$= 30 - 20.625$$
$$= 9.375 \text{ kN}$$

In ΔACD, $\tan\theta = \frac{CD}{AD} = \frac{1.5}{2} = 0.75$

$$\therefore \quad \theta = 36.87°$$

Now considering equilibrium of various joints one by one.

Joint-A

Let direction of forces F_{AC} and F_{AD} be assumed as shown in fig. 4.60 (a).

Resolving forces vertically,

$$F_{AC} \sin 36.87° = R_A = 20.625$$

$$\therefore \quad F_{AC} = \mathbf{34.37 \text{ kN (compression)}}$$ **Ans.**

Now resolving forces horizontally,

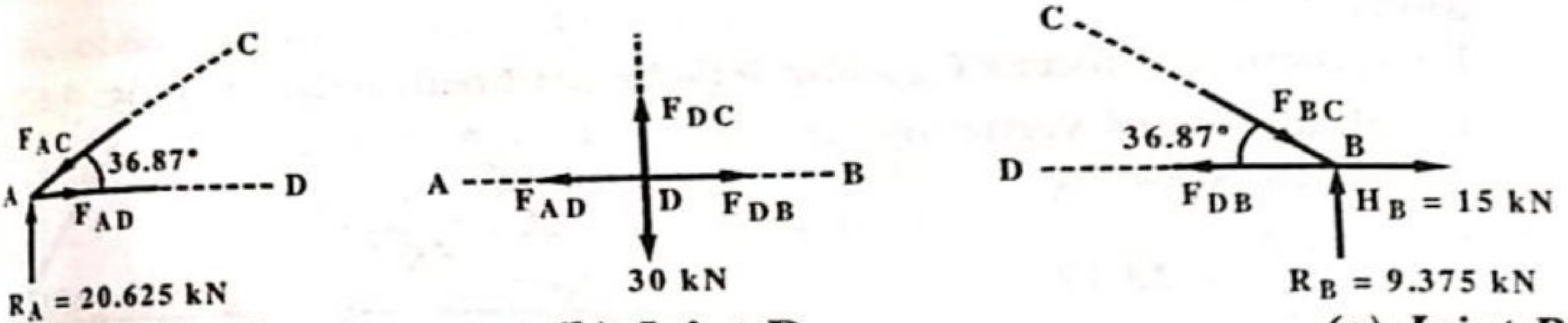
$$F_{AD} = F_{AC} \cos 36.87°$$
$$= 34.37 \times \cos 36.87°$$
$$= \mathbf{27.5 \text{ kN (tension)}}$$ **Ans.**

Joint-D

At joint-D, as shown in fig. 4.60 (b) there are four forces, out of which two are horizontal and two are vertical therefore,

$$F_{DB} = F_{AD}$$
$$= \mathbf{27.5 \text{ kN (tension)}}$$ **Ans.**

and $F_{DC} = \mathbf{30 \text{ kN (tension)}}$ **Ans.**



(a) Joint-A *(b) Joint-D* *(c) Joint-B*

Fig. 4.60

Joint-B

Let direction of force F_{BC} be assumed as shown in fig. 4.60 (c).

Resolving forces vertically,

$$F_{BC} \sin 36.87° = R_B = 9.375$$

$\therefore$ F_{BC} = **15.6 kN (compression)** **Ans.**

Prob.15. Analyse the truss shown below. All members are of 3.0 m in length.

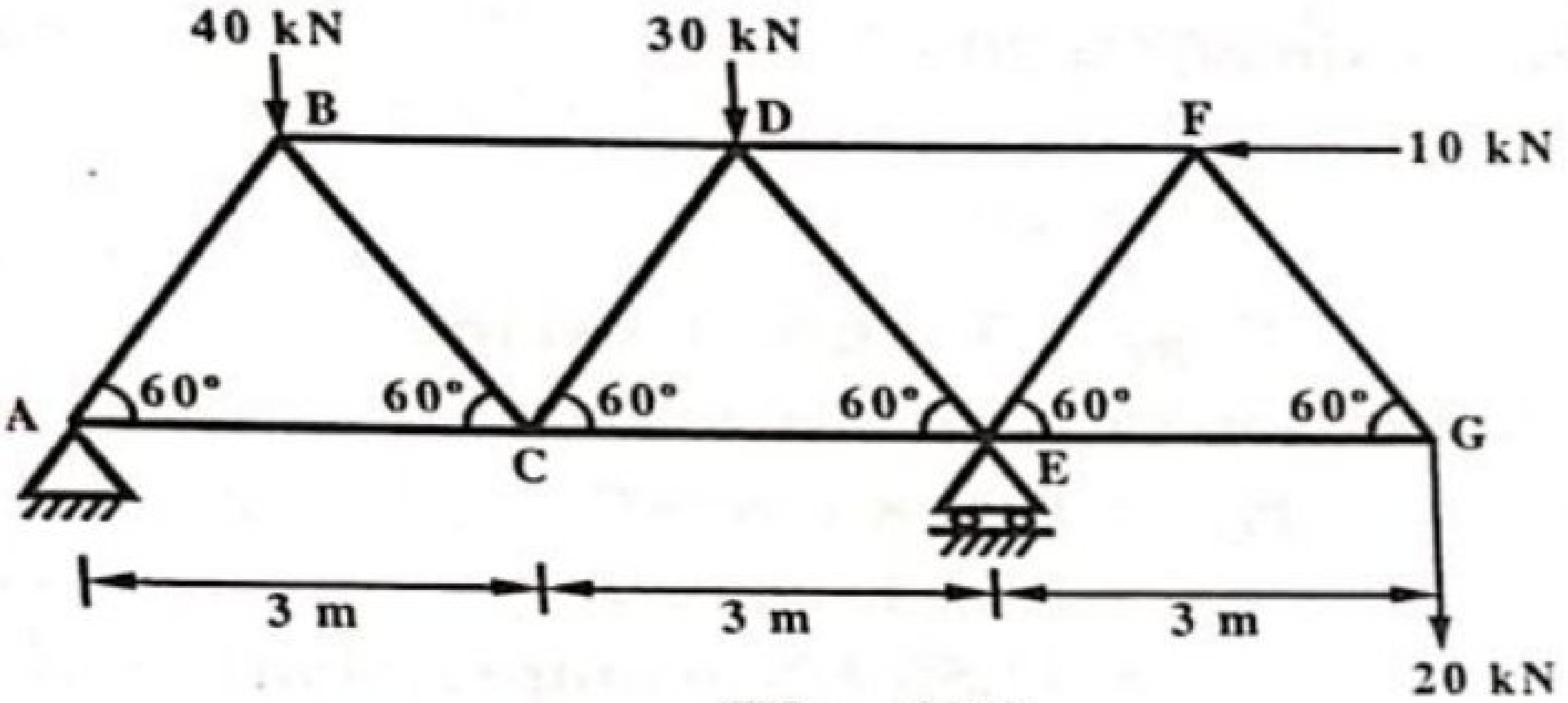


Fig. 4.61

(R.G.P.V., Dec. 2011)

Sol. Let R_A and R_E be the vertical reactions at supports A and E respectively. At hinged support there will also be a horizontal reaction H_A to balance the horizontal force, i.e. 10 kN. For equilibrium,

$$H_A = 10 \text{ kN}(\rightarrow)$$

Now taking moments about support A, we get

$$R_E \times 6 = 40 \times \frac{3}{2} + 30 \times \left(3 + \frac{3}{2}\right) + 20 \times 9 + 10 \times \frac{3}{2} \tan 60°$$

$$R_E \times 6 = 60 + 135 + 180 + 26 = 401$$

$\therefore$ $R_E = 66.83$ kN

and R_A = Total vertical load $- R_E$

$= 40 + 30 + 20 - 66.83 = 23.17$ kN

Now considering equilibrium of various joints one by one.

Joint-A

Let direction of forces F_{AB} and F_{AC} be assumed as shown in fig. 4.62(a

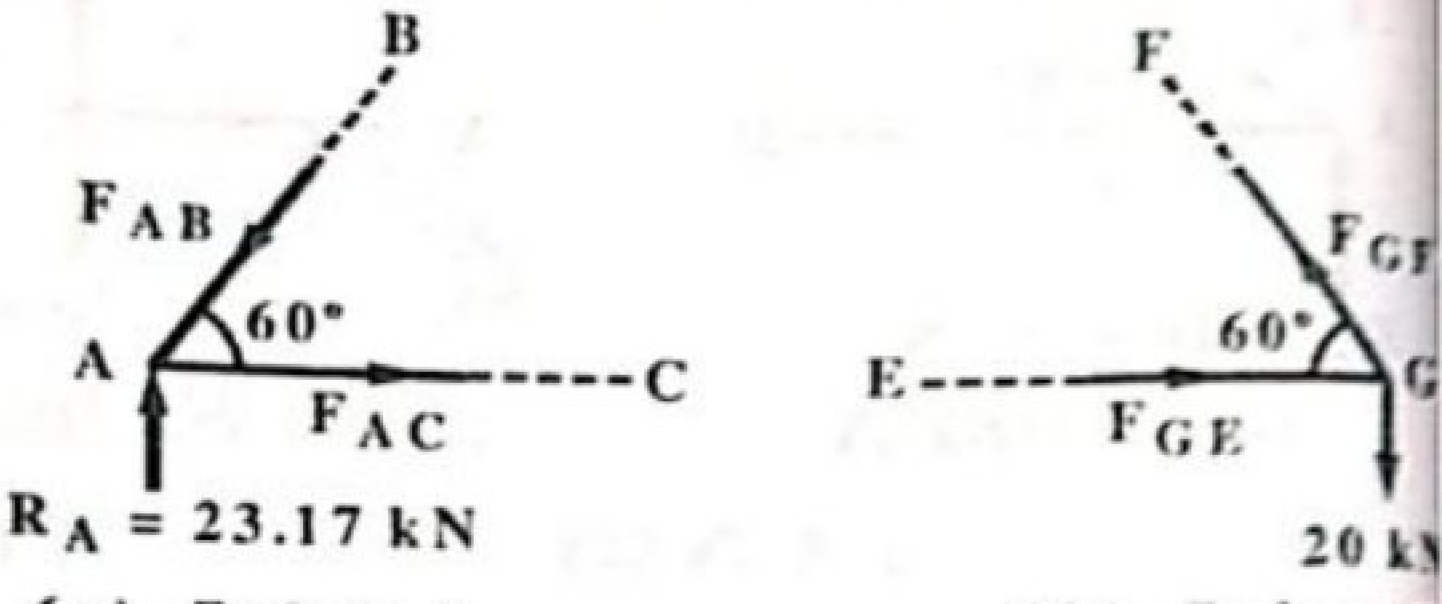
Resolving forces vertically, we get

$$F_{AB} \times \sin 60^\circ = R_A$$

$$F_{AB} \times \frac{\sqrt{3}}{2} = 23.17$$

$$\therefore \quad F_{AB} = \mathbf{26.75\ kN\ (compression)}$$

Ans.



(a) Joint-A *(b) Joint-G*

Fig. 4.62

Resolving forces horizontally, we get

$$F_{AC} = F_{AB} \times \cos 60^\circ$$

$$F_{AC} = 26.75 \times \cos 60^\circ = \mathbf{13.375\ kN\ (tension)}$$ Ans.

Joint-G

Let direction of forces F_{GF} and F_{GE} be assumed as shown in fig. 4.62 (b

Resolving forces vertically, we get

$$F_{GF} \times \sin 60^\circ = 20$$

$$F_{GF} \times \frac{\sqrt{3}}{2} = 20$$

$$\therefore \quad F_{GF} = \mathbf{23.1\ kN\ (tension)}$$ Ans.

Resolving forces horizontally, we get

$$F_{GE} = F_{GF} \times \cos 60^\circ$$

$$= 23.1 \times \cos 60^\circ$$

$$= \mathbf{11.55\ kN\ (compression)}$$ Ans.

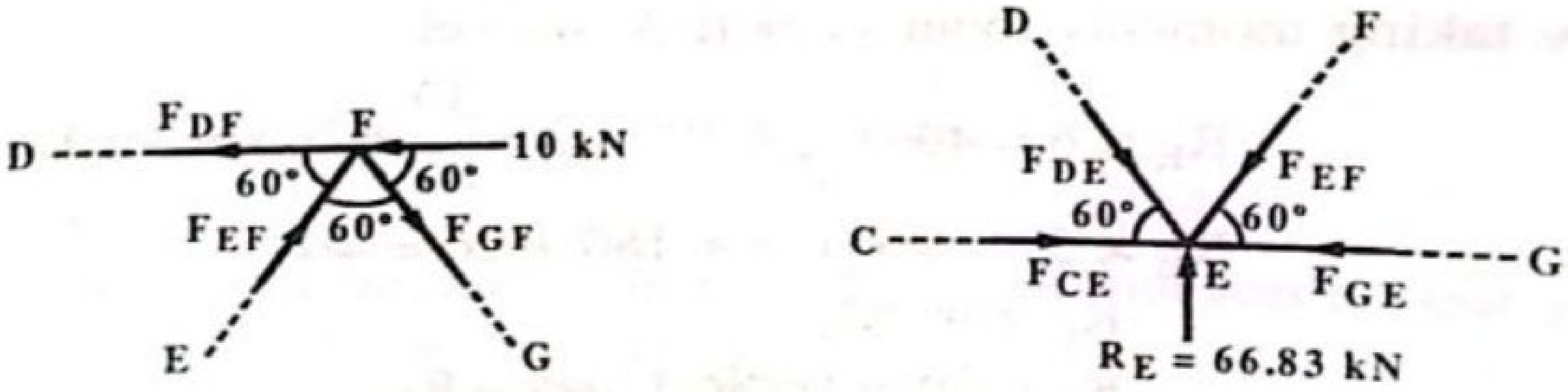
Joint-F

Let direction of forces F_{DF} and F_{EF} be assumed as shown in fig. 4.63 (a

Resolving forces vertically, we get

$$F_{EF} \sin 60^\circ = F_{GF} \sin 60^\circ$$

or $$F_{EF} = F_{GF} = \mathbf{23.1\ kN\ (compression)}$$ Ans



(a) Joint-F *(b) Joint-E*

Fig. 4.63

Resolving forces horizontally, we get

$$F_{DF} + 10 = F_{EF}\cos 60^\circ + F_{GF}\cos 60^\circ$$

$$F_{DF} + 10 = 23.1\cos 60^\circ + 23.1\cos 60^\circ$$

$$F_{DF} + 10 = 11.55 + 11.55 = 23.1$$

$\therefore$ $F_{DF} =$ **13.1 kN (tension)** **Ans.**

Joint-E

Let direction of forces F_{CE} and F_{DE} be assumed as shown in fig. 4.63 (b).

Resolving forces vertically, we get

$$F_{DE}\sin 60^\circ + F_{EF}\sin 60^\circ = R_E$$

$$F_{DE}\sin 60^\circ + 23.1\sin 60^\circ = 66.83$$

$$F_{DE}\sin 60^\circ + 20 = 66.83$$

$\therefore$ $F_{DE} = \dfrac{66.83 - 20}{\sin 60^\circ}$ = **54 kN (compression)** Ans.

Resolving forces horizontally, we get

$$F_{CE} + F_{DE}\cos 60^\circ = F_{GE} + F_{EF}\cos 60^\circ$$

$$F_{CE} + 54\cos 60^\circ = 11.55 + 23.1\cos 60^\circ$$

$$F_{CE} + 27 = 23.1$$

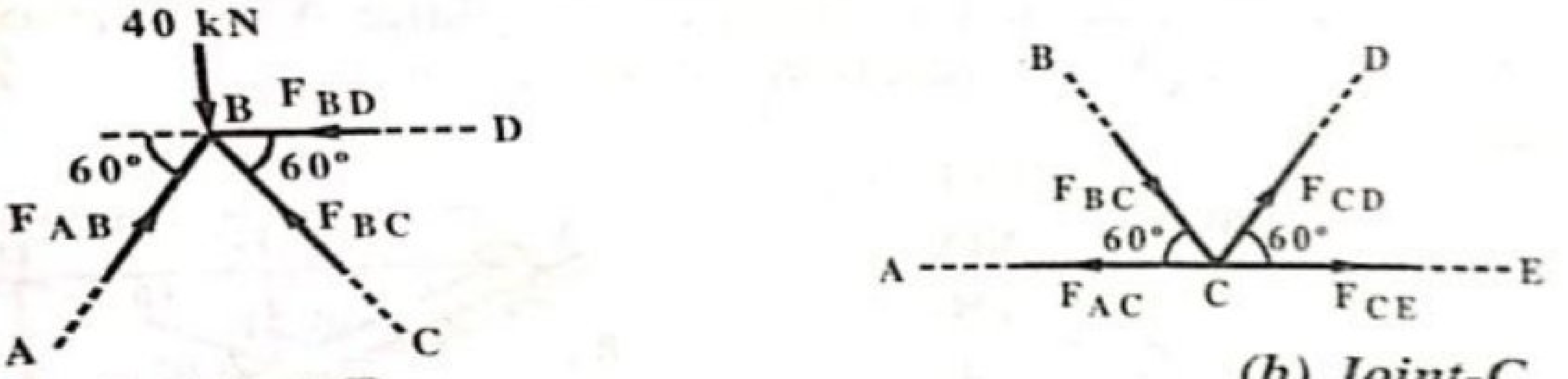
or $F_{CE} = 23.1 - 27 = -3.9$ kN

–ve sign indicates assumed direction of F_{CE} is wrong, thus,

$F_{CE} =$ **3.9 kN (tension)** **Ans.**

Joint-B

Let direction of forces F_{BC} and F_{BD} be assumed as shown in fig. 4.64 (a).



(a) Joint-B

(b) Joint-C

Fig. 4.64

Resolving forces vertically, we get

$$F_{AB}\sin 60^\circ + F_{BC}\sin 60^\circ = 40$$

$$26.75\sin 60^\circ + F_{BC}\sin 60^\circ = 40$$

$$26.75 + F_{BC} = \frac{40}{\sin 60^\circ} = 46.2$$

$\therefore$ $F_{BC} =$ **19.45 kN (compression)** **Ans.**

Resolving forces horizontally, we get

$$F_{BD} + F_{BC}\cos 60^\circ = F_{AB}\cos 60^\circ$$

$$F_{BD} + 19.45 \cos 60^\circ = 26.75 \cos 60^\circ$$

$$F_{BD} + 9.725 = 13.375$$

$$\therefore \quad F_{BD} = \mathbf{3.65\ kN\ (compression)}$$

Joint-C

Let direction of force F_{CD} be assumed as shown in fig. 4.64 (b). Resolving forces vertically, we get

$$F_{CD} \sin 60^\circ = F_{BC} \sin 60^\circ$$

or

$$F_{CD} = F_{BC} = \mathbf{19.45\ kN\ (tension)}$$

Prob.16. Determine axial forces in the members CF, FD, DG, GE** and **EB of simply supported loaded truss as shown in fig. 4.65.

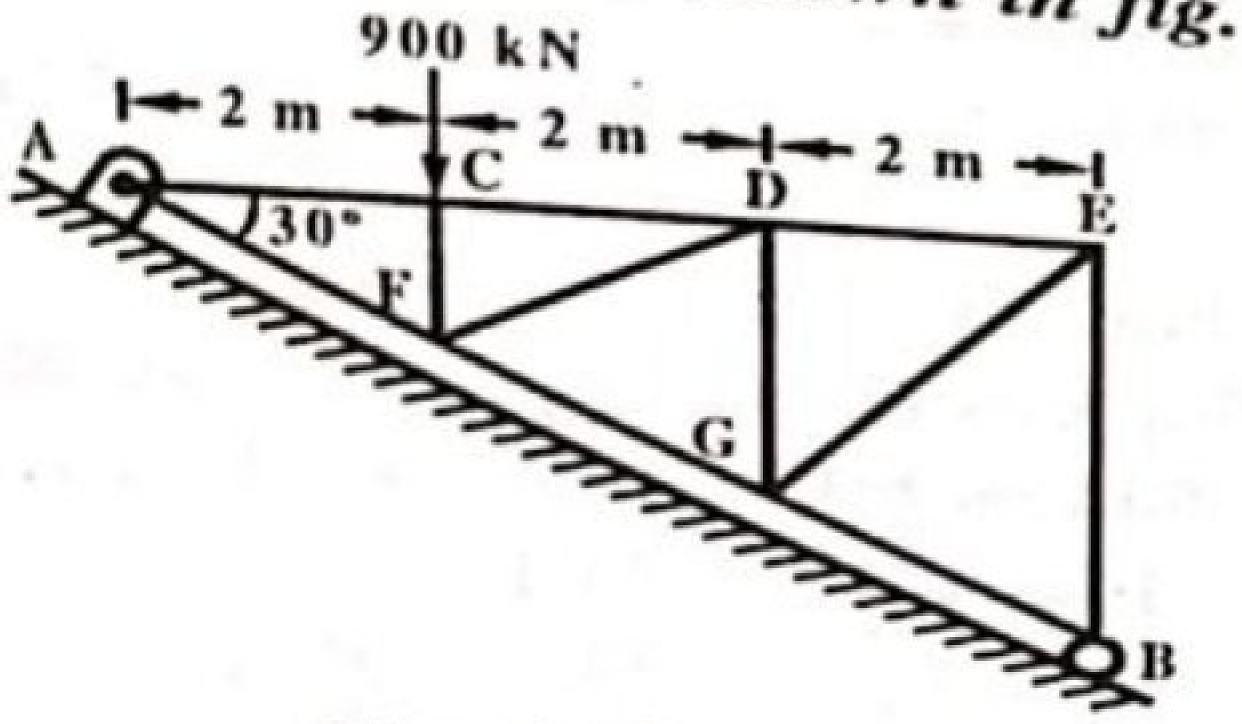


Fig. 4.65 ***(R.G.P.V., June 20***

Sol. Given truss is reproduced with various included angles in fig. 4 At roller support B, there will be only perpendicular reaction, while at hin support A, there will be both parallel and perpendicular reactions. Let R_A R_B be the reactions perpendicular to the inclined plane AB at spports A an respectively. Also let X_A be the reaction parallel to inclined plane AB.

In triangle ADG,

$$\tan 30^\circ = \frac{DG}{AD}$$

$$\frac{1}{\sqrt{3}} = \frac{DG}{4}$$

$$\therefore \quad DG = \frac{4}{\sqrt{3}} = 2.31\,\text{m}$$

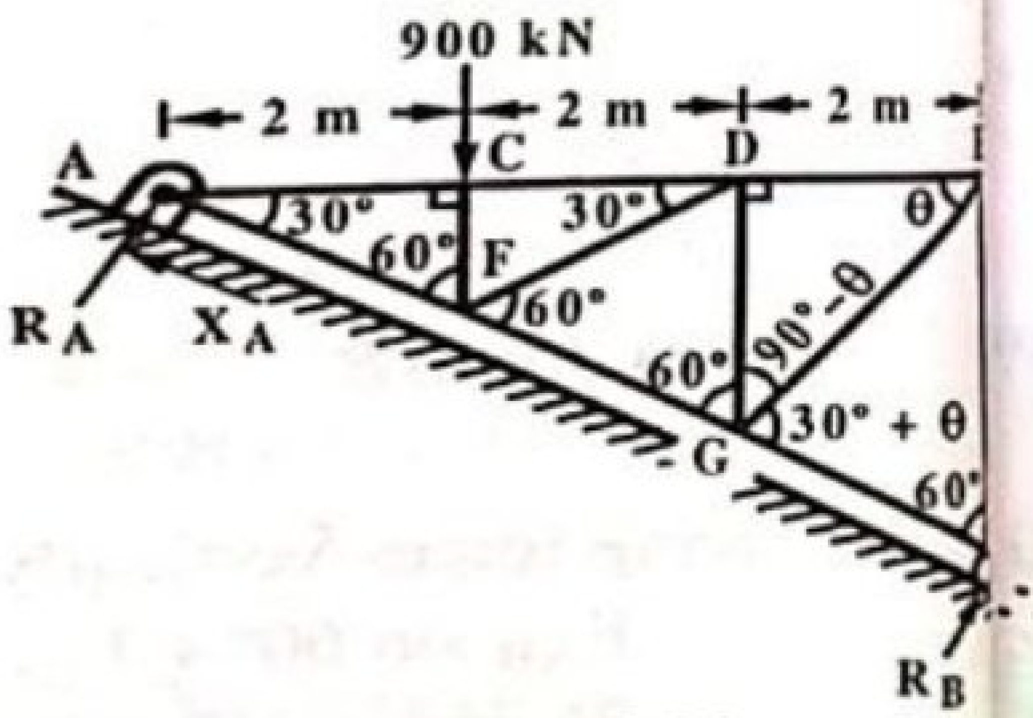


Fig. 4.66

and in triangle DEG,

$$\tan\theta = \frac{DG}{DE} = \frac{2.31}{2} = 1.155$$

$$\therefore \quad \theta = \tan^{-1}(1.155) = 49.1^\circ$$

Taking moments about support A,

$$R_B \times AB = 900 \times AC$$

$$R_B \times \frac{6}{\cos 30^\circ} = 900 \times 2 = 1800$$

$$R_B = \frac{1800 \cos 30^\circ}{6} = 259.8 \text{ kN}$$

∴

Now resolving forces along inclined plane AB,

$$X_A = 900 \sin 30^\circ = 450 \text{ kN}$$

nd resolving forces normal to the inclined plane AB,

$$R_A + R_B = 900 \cos 30^\circ$$

$$R_A + 259.8 = 779.4 \text{ or } R_A = 519.6 \text{ kN}$$

Now considering equilibrium of various joints one by one.

Joint-B

Let direction of forces F_{BG} and F_{BE} be assumed as shown in fig. 4.67 (a).

Resolving forces perpendicular to the plane AB,

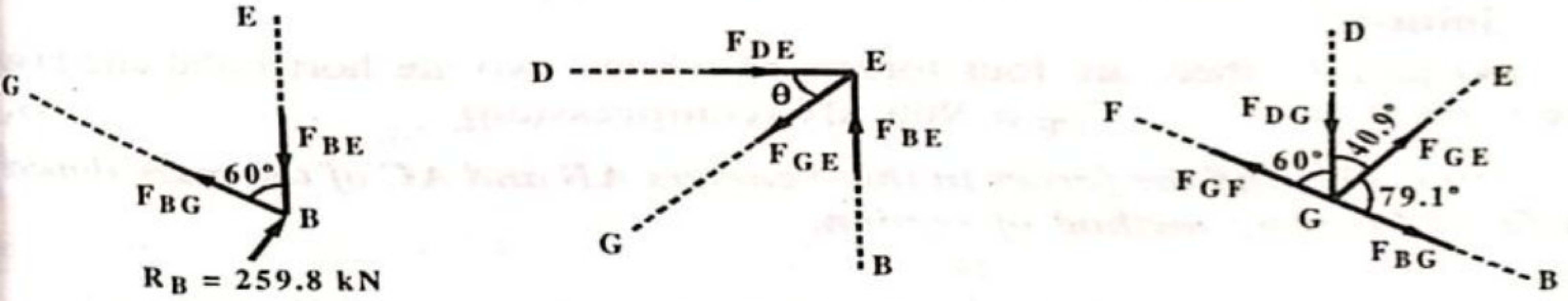
$$F_{BE} \sin 60^\circ = R_B = 259.8$$

or $F_{BE} =$ **300 kN (compression)** **Ans.**

Resolving forces along the plane AB,

$$F_{BG} = F_{BE} \cos 60^\circ$$

$$= 300 \times \cos 60^\circ = 150 \text{ kN (tension)}$$



(a) Joint-B ***(b) Joint-E*** ***(c) Joint-G***

Fig. 4.67

Joint-E

Let direction of forces F_{GE} and F_{DE} be assumed as shown in fig. 4.67 (b).

Resolving forces vertically,

$$F_{GE} \sin \theta = F_{BE}$$

$$F_{GE} \sin 49.1^\circ = 300$$

∴ $F_{GE} =$ **396.9 kN (tension)** **Ans.**

Resolving forces horizontally,

$$F_{DE} = F_{GE} \cos \theta$$

$$= 396.9 \times \cos 49.1^\circ = 259.8 \text{ kN (compression)}$$

Joint-G

Let direction of forces F_{DG} and F_{GF} be assumed as shown in fig. 4.67 (c).

Resolving forces normal to the inclined plane AB,

$$F_{DG} \sin 60^\circ = F_{GE} \sin 79.1^\circ$$

$$F_{DG} \times \frac{\sqrt{3}}{2} = 396.9 \times 0.9819$$

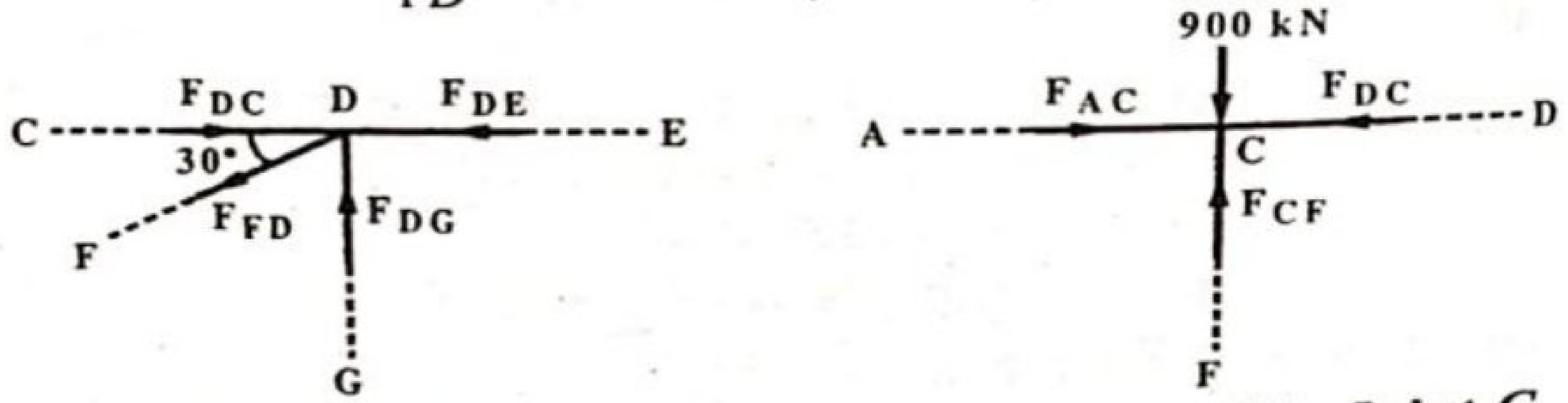
$$\therefore \quad F_{DG} = \mathbf{450\ kN\ (compression)}$$ Ar

Joint-D

Let direction of forces F_{DC} and F_{FD} be assumed as shown in fig. 4.68 (
Resolving forces vertically,

$$F_{FD} \sin 30° = F_{DG} = 450$$

$$\therefore \quad F_{FD} = \mathbf{900\ kN\ (tension)}$$ An



(a) Joint-D *(b) Joint-C*

Fig. 4.68

Joint-C

At joint-C, there are four forces, of which, two are horizontal and tw are vertical, thus, $F_{CF} =$ **900 kN (compression)** An

Prob.17. Find the forces in the members AB and AC of the truss show in fig. 4.69 using method of section.

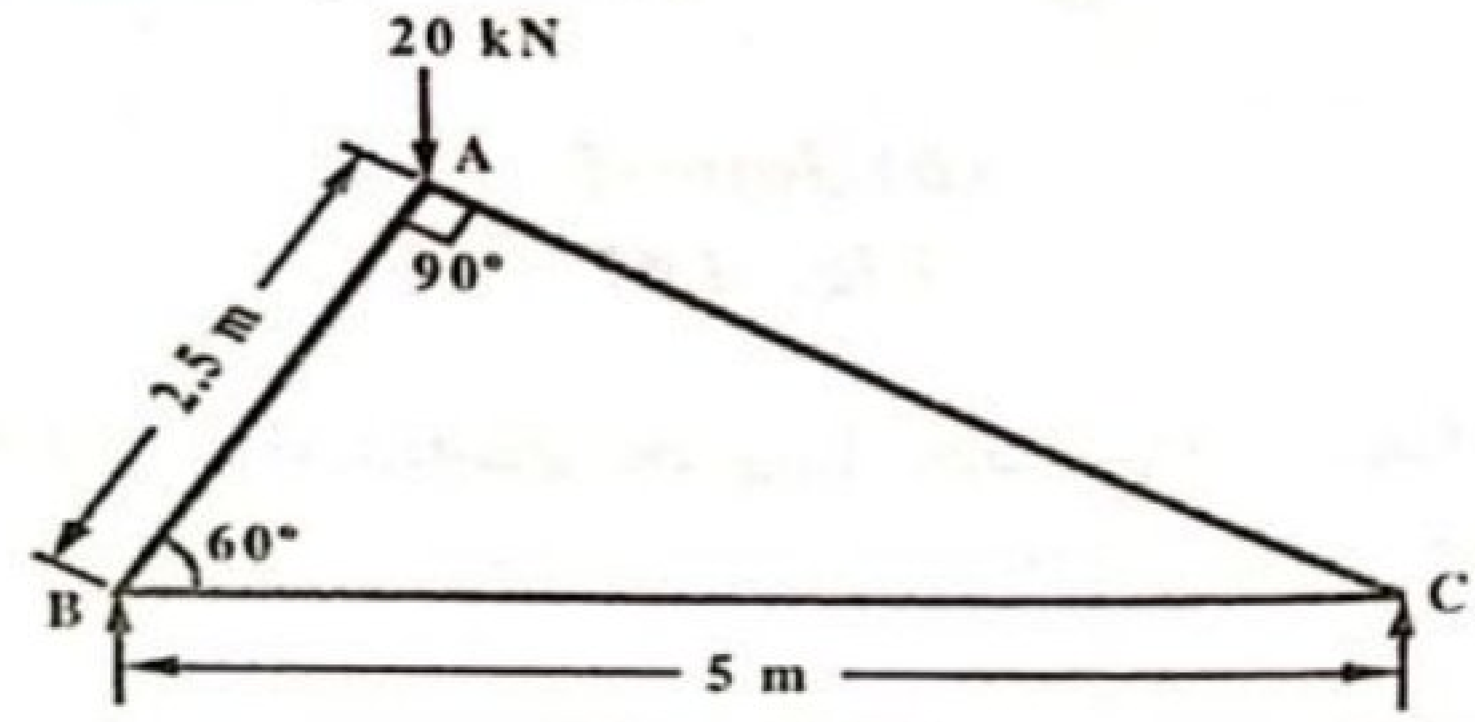


Fig. 4.69 ***(R.G.P.V., June 201***

Sol. Let R_B and R_C be the vertical reactions at supports B and C respective
The distance of line of action of the vertical load of 20 kN from support

$$= AB \cos 60° = 2.5 \times 0.5 = 1.25 \text{ m}$$

Taking moments of various forces about support B, we get

$$R_C \times 5 = 20 \times 1.25 = 25$$

$$\therefore \quad R_C = 5 \text{ kN}$$

and $$R_B = \text{Total vertical load} - R_C$$

$$= 20 - 5 = 15 \text{ kN}$$

First draw a section line ①-① passing through members AB and BC as shown in fig. 4.70. Consider the equilibrium of the left part of the truss as shown by solid lines in figure. Direction of forces in the members AB an BC be assumed as shown in fig. 4.70.

Taking moments of the forces acting in the left part of the truss about point C and equating to zero,

$$F_{AB} \times 5 \sin 60° = R_B \times 5$$

$$F_{AB} \times \frac{\sqrt{3}}{2} = 15$$

or $F_{AB} =$ **17.32 kN (compression)** **Ans.**

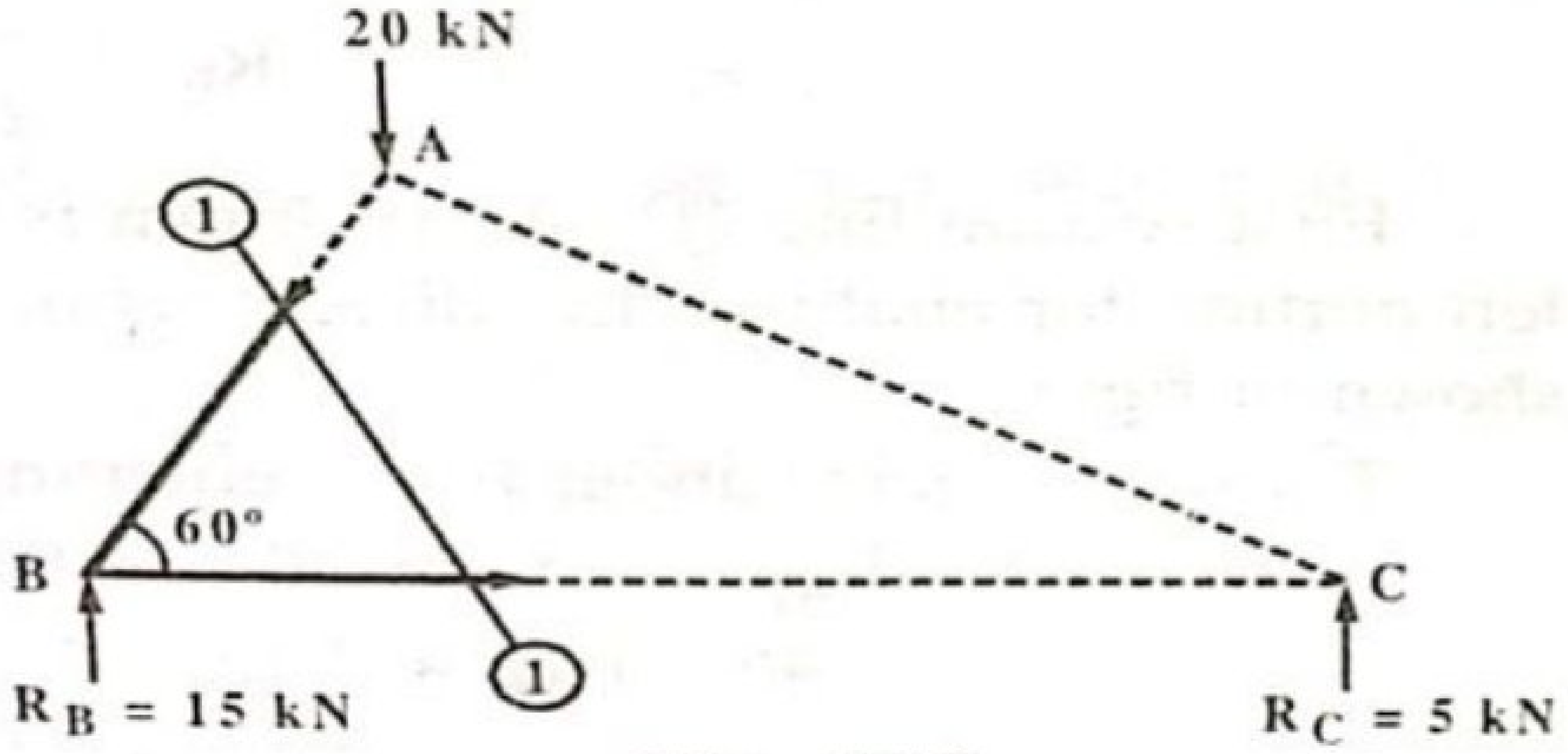


Fig. 4.70

Now draw another section line ②-② passing through members AC and BC as shown in fig. 4.71. Consider the equilibrium of the right part of the truss as shown by solid lines. Direction of forces in the members AC and BC be assumed as shown in fig. 4.71.

Taking moments of the forces acting in the right part of the truss about point B and equating to zero,

$$F_{AC} \times 5 \sin 30° = R_C \times 5$$

$$F_{AC} \times \frac{1}{2} = 5$$

or $F_{AC} =$ **10 kN (tension)** **Ans.**

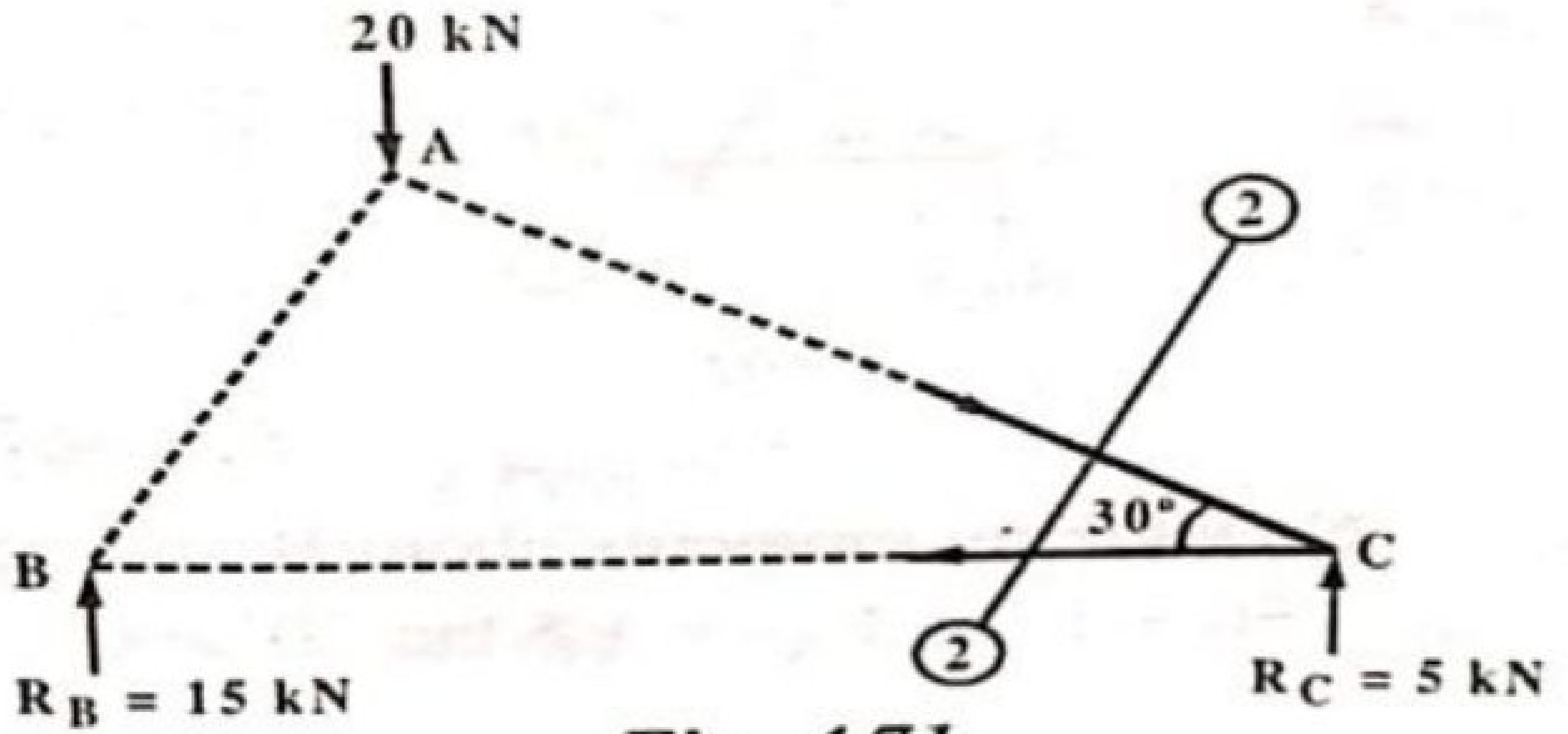


Fig. 4.71

Prob.18. ***Determine the magnitude and nature of forces in all the members of a truss shown in fig. 4.72. Tabulate the results.***

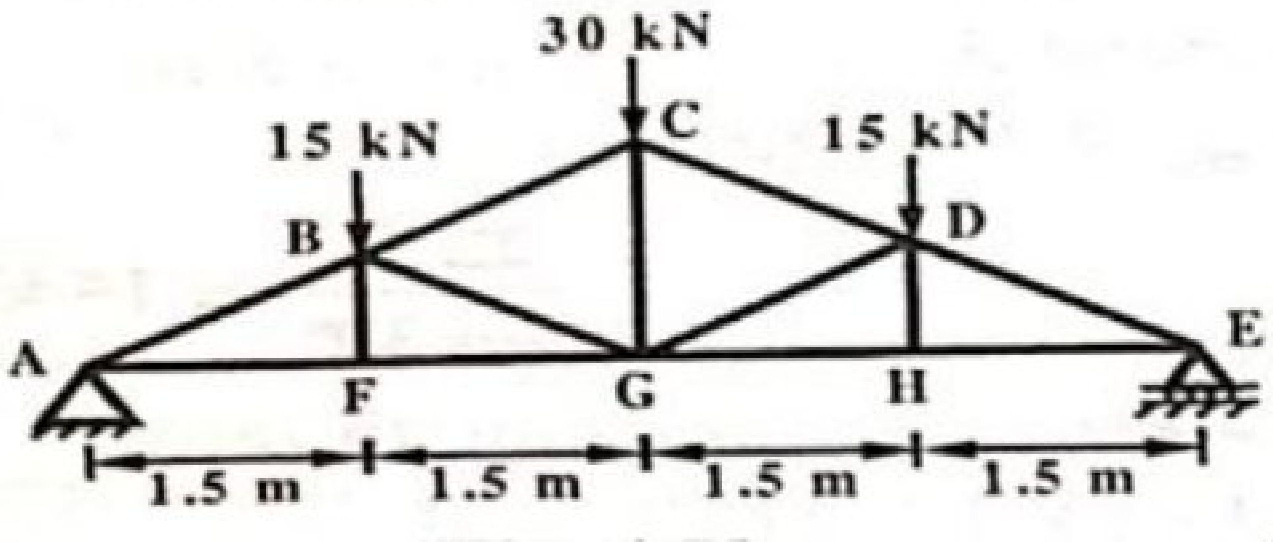


Fig 4.72 ***(R.G.P.V., June 2009)***

Sol. Various joints of the truss are named as shown in fig. 4.72.
Let ∠CAG = ∠CEG = 30°

Let R_A and R_E be the vertical reactions at supports A and E respectively. As truss is symmetrically loaded therefore both reactions will be equal and magnitude of half of total vertical load, i.e.

$$R_A = R_E = \frac{1}{2}\ (15 + 30 + 15) = 30 \text{ kN}$$

First section line ①-① as drawn is shown in fig. 4.73 (a). Considering left portion for analysis. Let directions of forces F_{AB} and F_{AF} be assumed as shown in figure.

Taking moments about F and equating to zero

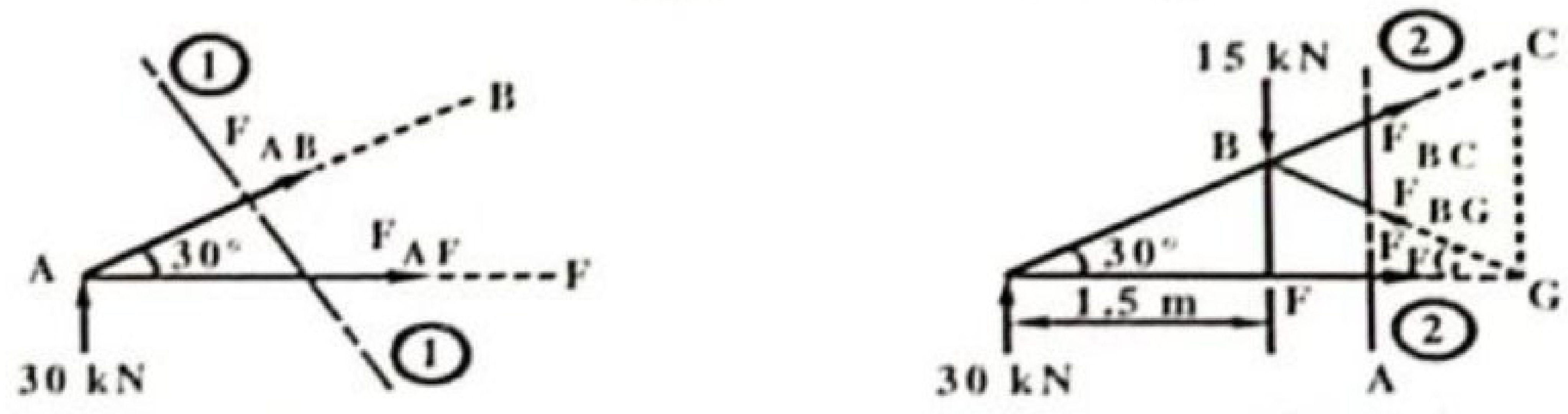
$$-30 \times 1.5 - F_{AB} \times 1.5 \sin 30^\circ = 0$$

$$-45 - F_{AB} \times 0.75 = 0$$

$$\therefore \qquad F_{AB} = -60 \text{ kN}$$

–ve sign means assumed direction of F_{AB} is wrong and there will be a compressive force in AB, i.e.

$$F_{AB} = \mathbf{60\ kN\ (compression)} \qquad \textbf{Ans.}$$



(a) *(b)*

Fig. 4.73

Now taking moments about B and equating to zero

$$-30 \times 1.5 + F_{AF} \times 1.5 \tan 30^\circ = 0$$

$$F_{AF} = \frac{45}{1.5 \tan 30^\circ} = \mathbf{52\ kN\ (tension)} \qquad \textbf{Ans.}$$

Another section line ②-② as shown in fig. 4.73 (b), is drawn and directions of forces F_{BC}, F_{BG} and F_{FG} be assumed as shown in figure.

Taking moments about A and equating to zero

$$15 \times 1.5 - F_{BG} \times 3 \sin 30^\circ = 0$$

$$\therefore \qquad F_{BG} = \frac{22.5}{3 \sin 30^\circ} = \mathbf{15\ kN\ (compression)} \quad \textbf{Ans.}$$

Taking moments about B and equating to zero

$$-(30 \times 1.5) + F_{FG} \times 1.5 \tan 30^\circ = 0$$

$$-45 + F_{FG} \times 0.866 = 0$$

$$\therefore \qquad F_{FG} = \frac{45}{0.866} = \mathbf{52\ kN\ (tension)} \qquad \textbf{Ans.}$$

Now taking moments about G and equating to zero

$$-(30 \times 3) + (15 \times 1.5) - F_{BC} \times 3 \sin 30° = 0$$

$$-67.5 - 1.5\, F_{BC} = 0$$

$$\therefore \quad F_{BC} = -45 \text{ kN}$$

-ve sign means assumed direction of F_{BC} is wrong, and there will be a compressive force in BC, i.e.

F_{BC} = **45 kN (compression)** **Ans.**

Now at joint F, there are three forces, out of which forces F_{AF} and F_{FG} are collinear (equal and opposite), therefore force in third member, i.e. BF will be zero.

Hence

F_{BF} = **0** **Ans.**

As whole truss is symmetrical, therefore

$F_{DE} = F_{AB}$ = **60 kN (compression)** **Ans.**

$F_{EH} = F_{AF}$ = **52 kN (tension)** **Ans.**

$F_{DG} = F_{BG}$ = **15 kN (compression)** **Ans.**

$F_{CD} = F_{BC}$ = **45 kN (compression)** **Ans.**

$F_{GH} = F_{FG}$ = **52 kN (tension)** **Ans.**

$F_{DH} = F_{BF}$ = **0** **Ans.**

Now to determine the force in member CG resolving forces at joint-C vertically,

$$-F_{BC} \cos 60° - F_{CD} \cos 60° + 30 + F_{CG} = 0$$

$$-22.5 - 22.5 + 30 + F_{CG} = 0$$

$\therefore$ F_{CG} = **15 kN (tension)** **Ans.**

Results are tabulated below –

S.No.	*Member Name*	*Magnitude and Nature of Force*
1	AB	60 kN (compression)
2	BC	45 kN (compression)
3	CD	45 kN (compression)
4	DE	60 kN (compression)
5	AF	52 kN (tension)
6	FG	52 kN (tension)
7	GH	52 kN (tension)
8	HE	52 kN (tension)
9	BF	0
10	BG	15 kN (compression)
11	CG	15 kN (tension)
12	DG	15 kN (compression)
13	DH	0

FRICTIONAL FORCE IN EQUILIBRIUM PROBLEMS

Q.50. Define friction.

Ans. When two bodies kept in physical contact move, or tend to move with respect to each other, a tangential force is found to set up at the contact surface which opposes this relative motion. This tangential opposing force is known as ***force of friction*** or simply ***friction.*** Therefore friction can be defined as the contact resistance developed between the contacting surfaces when one of the bodies moves, or tends to move, over the other.

Q.51. Friction is a necessary evil. Comment on the validity of this statement. ***(R.G.P.V., Dec. 2008)***

Ans. Friction is the contact resistance developed between the contacting surfaces of two bodies, when one of the bodies moves, or tends to move, over the other. Due to their opposing nature frictional forces are always accompanied by loss of energy, but still, they are often found to be useful. For example, without friction it would be impossible for us to walk, ride a vehicle or pick some object from the floor. The friction is thus rightly called as a necessary evil. In many engineering applications, such as bearings and gears (as in an automobile) and the flow of fluids in pipes, friction is quite undesirable, and has to be minimised. While in many other engineering applications, such as brakes and clutches (as in an automobile) and in belt drive (for power transmission) friction is quite necessary, as their working depends on friction.

Q.52. What do you understand by the following –
(i) Static friction (ii) Limiting friction (iii) Kinetic friction.
(R.G.P.V., April 2009)

Ans. *(i)* ***Static Friction*** – When a force is applied to a body, it remains at rest initially, due to friction. The frictional force acting in this condition is known as static friction. Thus, static friction is the friction experienced by a body, when it is at rest.

(ii) ***Limiting Friction*** – When a body lying over another body is being pushed gently, it does not move, due to the frictional force which opposes its motion. When we push the body little harder, it still remains unmoved. This shows that the force of friction has increased itself to become equal and opposite to the applied force. Therefore, force of friction can adjust its magnitude, so as to become exactly equal to the force applied to produce motion.

However, there is a limit beyond which force of friction cannot increase. When applied force exceeds this limit, the body begins to move. This maximum value of frictional force, just before the body begins to move, is known as ***limiting friction***.

(iii) Kinetic Friction – The friction experienced by a body when, it is in motion, is known as ***dynamic*** or ***kinetic friction***. Dynamic friction can be of two types –

(a) Sliding friction, and (b) Rolling friction.

The frictional forces which set up due to sliding of one body over the other is known as sliding friction and when this is caused by the rolling of one body over the other is known as rolling friction.

Q.53. Explain the Coulomb's law of friction. ***(R.G.P.V., June 2010)***

Or

State and explain Coulomb's laws of dry friction.

(R.G.P.V., June 2006, 2009)

Ans. Coulomb in 1781, on the basis of his experiments gives some laws of friction for dry or solid friction. These laws can be classified as –

(i) Laws of static friction (ii) Laws of dynamic friction.

(i) Laws of Static Friction – (a) The frictional force always acts in a direction opposite to that in which body tends to move.

(b) The magnitude of force of friction is exactly equal to the force applied, as long as the body is at rest.

(c) The limiting friction force bears a constant ratio to the normal reaction between two surfaces. Mathematically,

$$F/R = \text{Constant.}$$

(d) The limiting frictional force is independent of the shape and area of surfaces in contact. But, it depends upon the nature (smoothness/roughness) of surfaces in contact.

(ii) Laws of Dynamic Friction – (a) The frictional force always acts in a direction opposite to that in which body is moving.

(b) The magnitude of dynamic friction bears a constant ratio to the normal reaction between the two surfaces but this ratio is slightly less than that in case of limiting friction.

(c) The force of friction remains constant for moderate speeds but it decreases slightly with the increase of speed.

(d) Dynamic friction is increased by reversal of motion.

(e) Dynamic friction decreases with time, due to heating of rubbing surfaces.

Q.54. Define the following terms –

(i) Coefficient of friction
(ii) Angle of friction
(iii) Cone of friction.

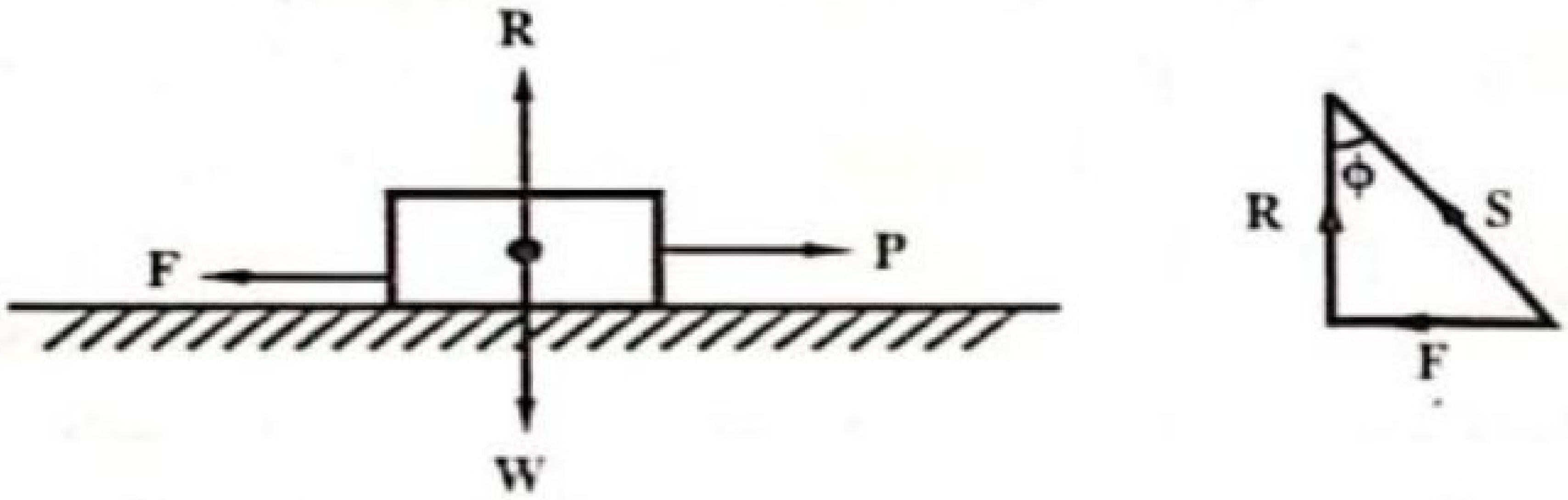
Ans. (i) Coefficient of Friction – Coefficient of friction (μ) can be defined as, the ratio of the limiting frictional force (F) to the normal reaction (R). Mathematically,

$$\mu = \frac{F}{R}$$

When surfaces in contact are stationary, the coefficient of friction is known as coefficient of static friction and denoted by μ_s. When surfaces in contact are moving relative to each other the frictional force decreases somewhat from the limiting static frictional force. In this case coefficient of friction is known as coefficient of kinetic friction (μ_k).

(ii) Angle of Friction – It is defined as the angle made by the resultant of the normal reaction (R) and the limiting force of friction (F) with the normal reaction (R). It is denoted by ϕ.

Consider a block of weight W is resting on a rough surface and subjected to pull P as shown in fig. 4.74 (a).



(a) *(b)*

Fig. 4.74 Angle of Friction

Let S = Resultant of F and R, which acts at an angle ϕ with the R as shown in fig. 4.74 (b). From geometry of fig. 4.74 (b),

$$\tan \phi = F/R$$

But $F/R = \mu$, coefficient of friction, hence

$$\tan \phi = \mu \qquad \text{...(i)}$$

or

$$\phi = \tan^{-1} (\mu)$$

(iii) Cone of Friction. – When a body tends to move on a surface due to a pull P, a frictional force F acts opposite to the direction of motion, and a reaction R_N acts normal to the surface. The resultant of F and R_N, R makes an angle ϕ with the R_N, as shown in fig. 4.75.

Now if P is made to revolve about a vertical axis, then R must also revolve about a vertical axis. As R revolves, it generates a cone having normal reaction R_N as its axis, ϕ as its semi-vertical angle and the point of intersection of R and R_N as its vertex. This cone is called ***cone of friction.*** The resultant reaction always lies within this cone.

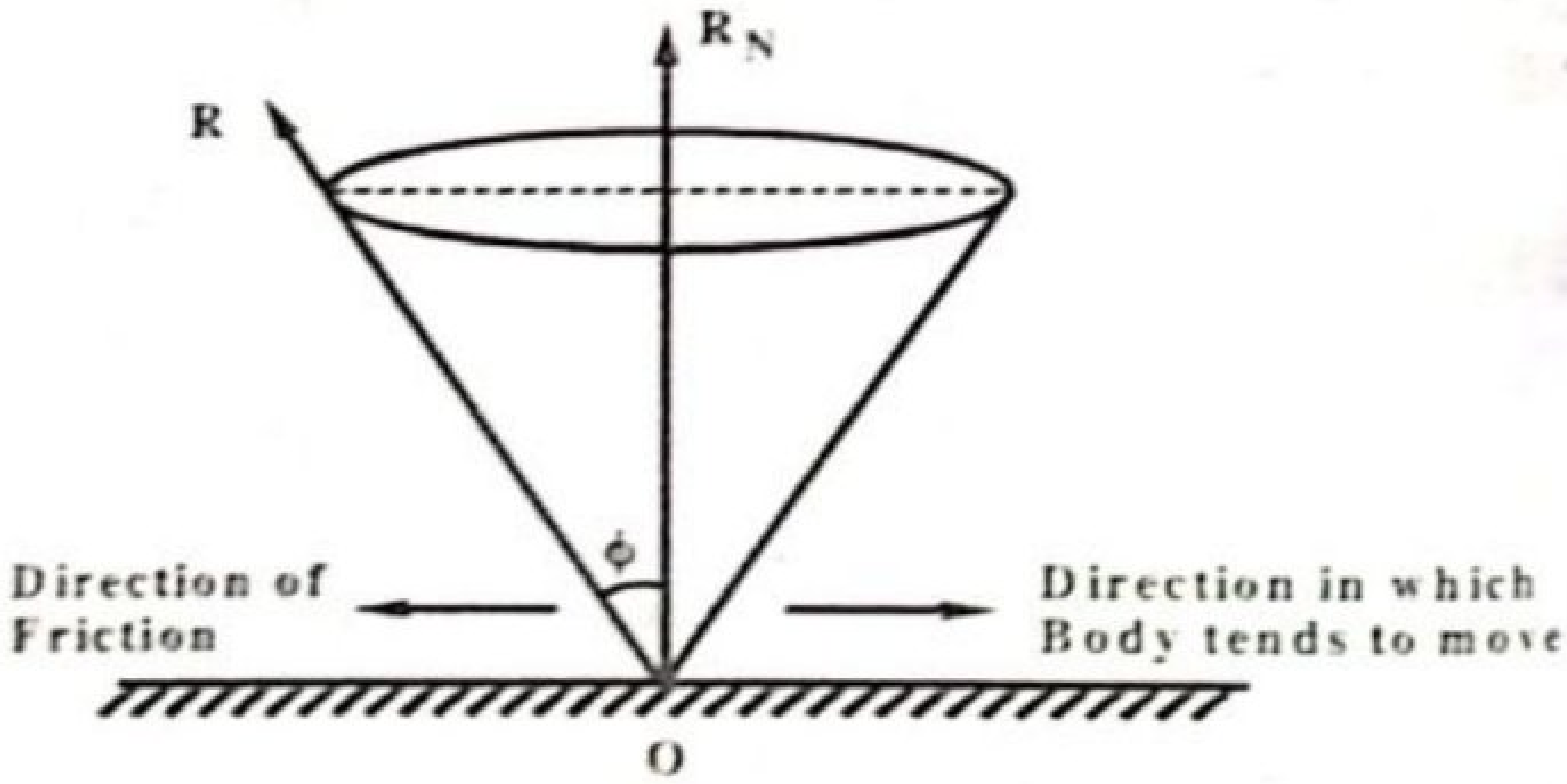


Fig. 4.75

Q.55. Define angle of repose and show that it is equal to the angle of friction.

Ans. Consider a block resting on an inclined plane as shown in fig. 4.76. Tangential component of the block's weight tends to slide the block in downward direction. But frictional force opposes this motion and block thus remains at rest. However, if inclination of plane is increased with the horizontal surface the block start to slide downward due to its own weight. This angle at which block starts sliding itself is known as ***angle of repose*** (α).

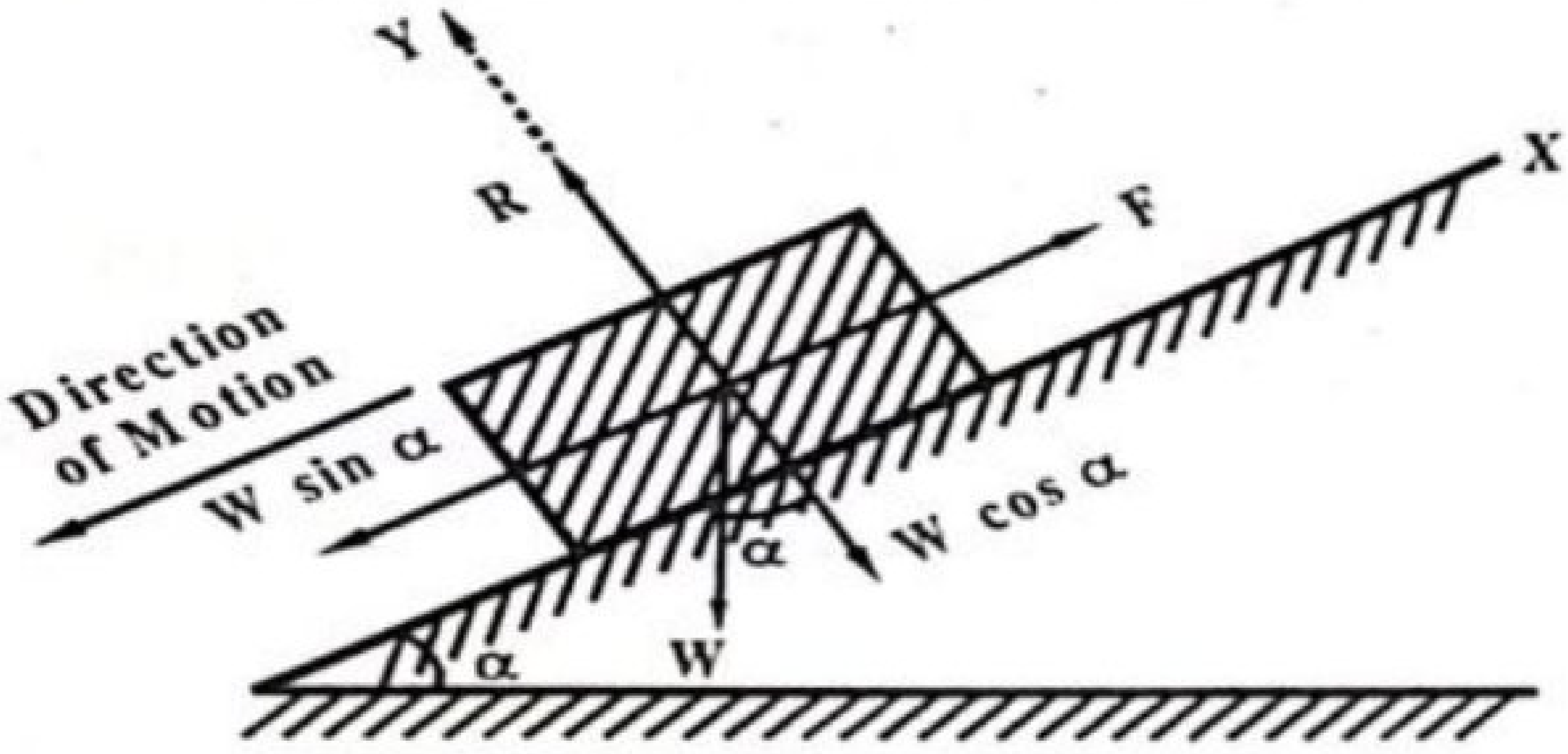


Fig. 4.76 Angle of Repose

Let W = Weight of the block

α = Angle of inclination of plane with the horizontal surface, at which the motion is impending, i.e. Angle of repose.

Various forces acting on block are shown in fig. 4.76.

Resolving the forces along the inclined plane, we have

$$F = \mu R = W \sin \alpha \qquad \text{...(ii)}$$

and on resolving forces along a plane perpendicular to inclined plane, we get

$$R = W \cos \alpha \qquad \text{...(iii)}$$

Dividing equation (ii) by equation (iii), we get

$$\mu = \tan \alpha \qquad \text{...(iv)}$$

By comparing equations (i) and (iv), we get

$$\tan \alpha = \tan \phi$$

or

$$\alpha = \phi$$

Thus angle of repose and angle of friction are numerically equal when motion is impending.

Q.56. Derive relation for the pull required to just move a body resting on a rough horizontal plane.

Or

Obtain an expression for minimum force required to move a body on a horizontal plane. ***(R.G.P.V., Dec. 2013)***

Ans. Consider a body of weight W resting on a rough horizontal plane and subjected to a pull P which acts at an angle θ with the horizontal as shown in fig. 4.77.

Let R = Normal reaction between contact surfaces

μ = Coefficient of friction for contact surfaces

$F = \mu R$ = Frictional force between contact surfaces.

Resolving forces vertically,

$$R + P \sin\theta = W$$

or

$$R = W - P \sin\theta \qquad ...(i)$$

and resolving forces horizontally,

$$F = P \cos\theta$$

or

$$\mu R = P \cos\theta$$

Substituting value of R from equation (i), we get

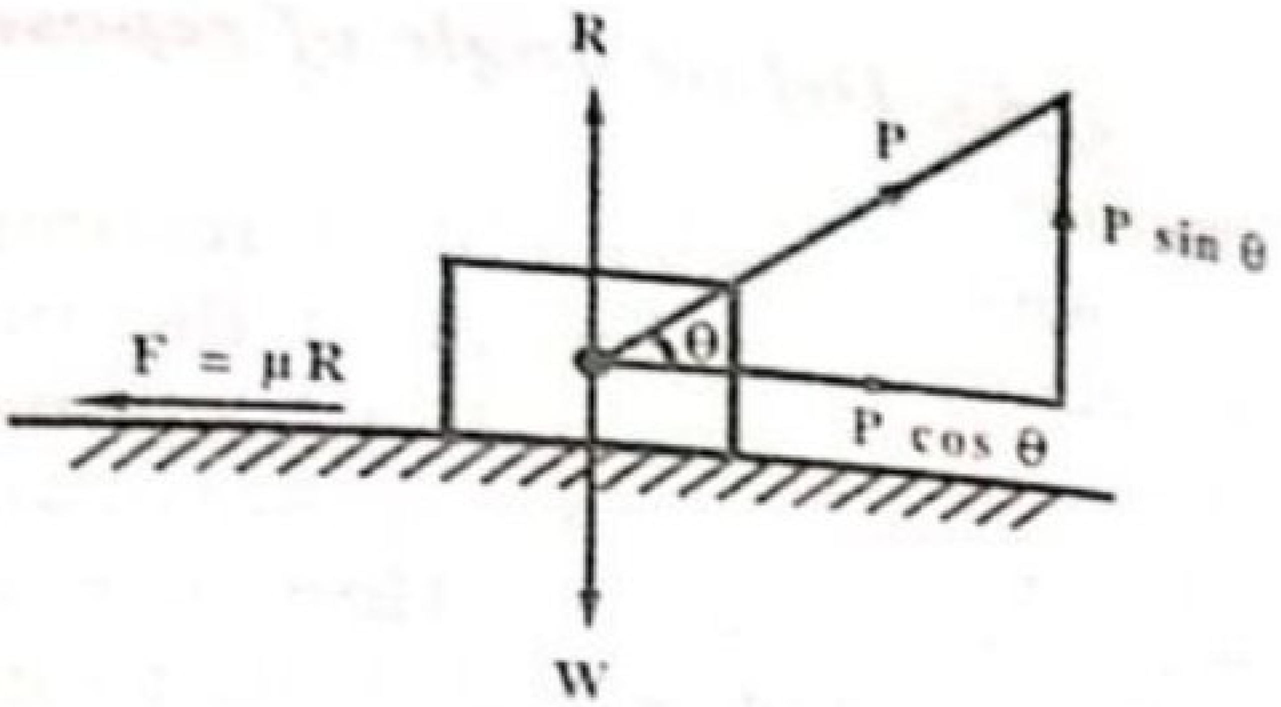


Fig. 4.77

$$\mu (W - P \sin\theta) = P \cos\theta$$

or

$$P(\cos\theta + \mu \sin\theta) = \mu W$$

$$P(\cos\theta + \tan\phi \sin\theta) = W \tan\phi \qquad (\because \mu = \tan\phi)$$

$$\frac{P(\cos\theta . \cos\phi + \sin\theta . \sin\phi)}{\cos\phi} = W \frac{\sin\phi}{\cos\phi} \quad \text{or} \quad P = \frac{W \sin\phi}{\cos(\theta - \phi)}$$

This force P will be minimum, when cos (θ – φ) become maximum, i.e.

$$\cos(\theta - \phi) = 1$$

$$\theta - \phi = 0$$

$$\theta = \phi$$

$$\therefore \qquad P_{min} = W \sin\phi$$

This is the minimum force which when applied, the body is just begin to move.

If instead of being pulled body is pushed by a force P as shown in fig. 4.78, then

$$P = \frac{W \sin\phi}{\cos(\theta + \phi)}$$

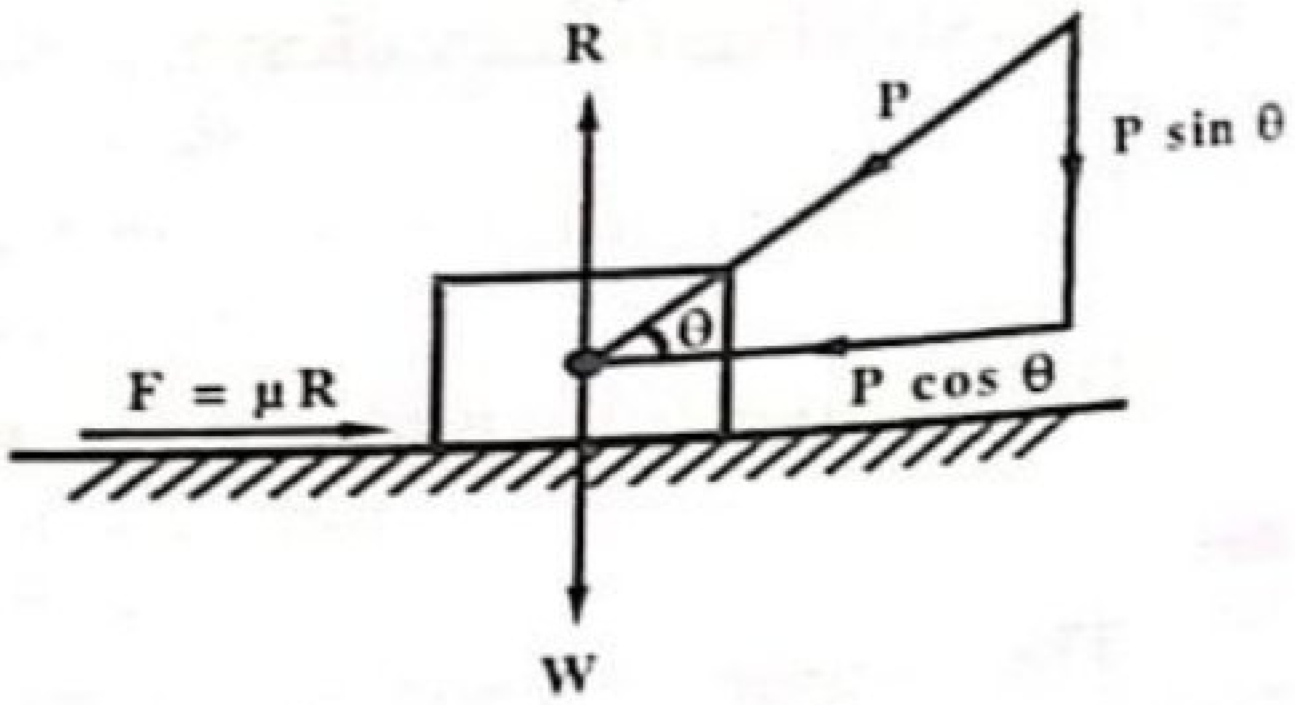


Fig. 4.78

Q.57. Discuss equilibrium of a body resting on a rough inclined plane under various conditions of applied force.

Ans. Consider a body of weight W resting on a rough plane inclined at an angle α with the horizontal as shown in fig. 4.79.

When angle of inclination is less than angle of repose (or angle of friction) the body will remain in equilibrium. In this condition an upward or downward force is required to move the body up or down. But, when angle of inclination of plane is more than the angle of friction, the body will start to move down, thus an upward force

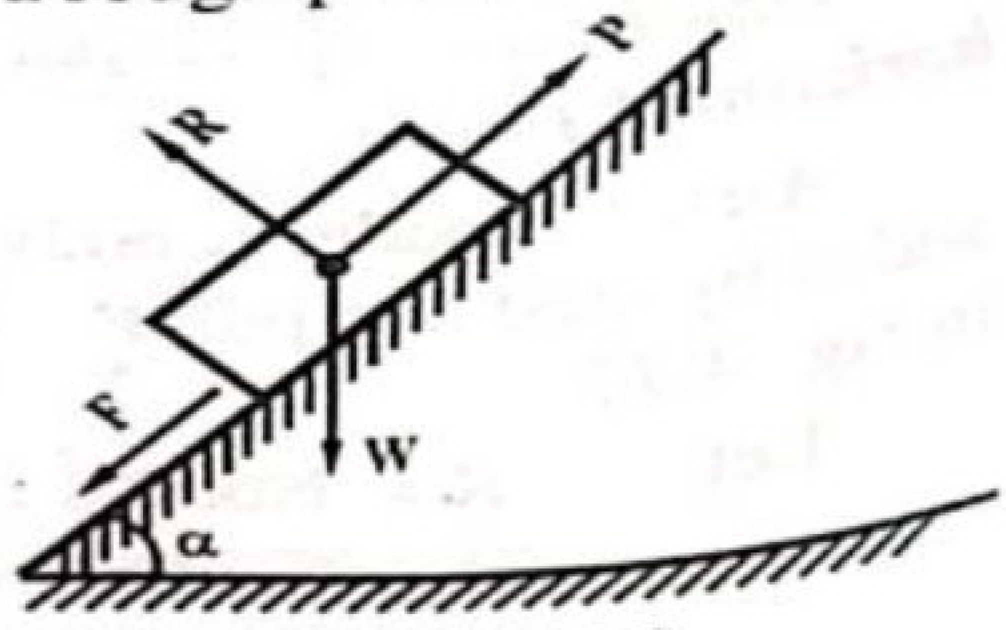


Fig. 4.79

will be required to resist the motion of the body. This force may be applied in three ways, which are –

- (i) Force applied at an angle to the inclined plane.
- (ii) Force applied along the inclined plane.
- (iii) Force applied horizontally.

(i) Force Applied at An Angle to the Inclined Plane – Consider a body of weight W, resting on a rough plane inclined at an angle α with the horizontal.

Let R = Normal reaction

μ = Coefficient of friction between the body and plane

ϕ = Angle of friction.

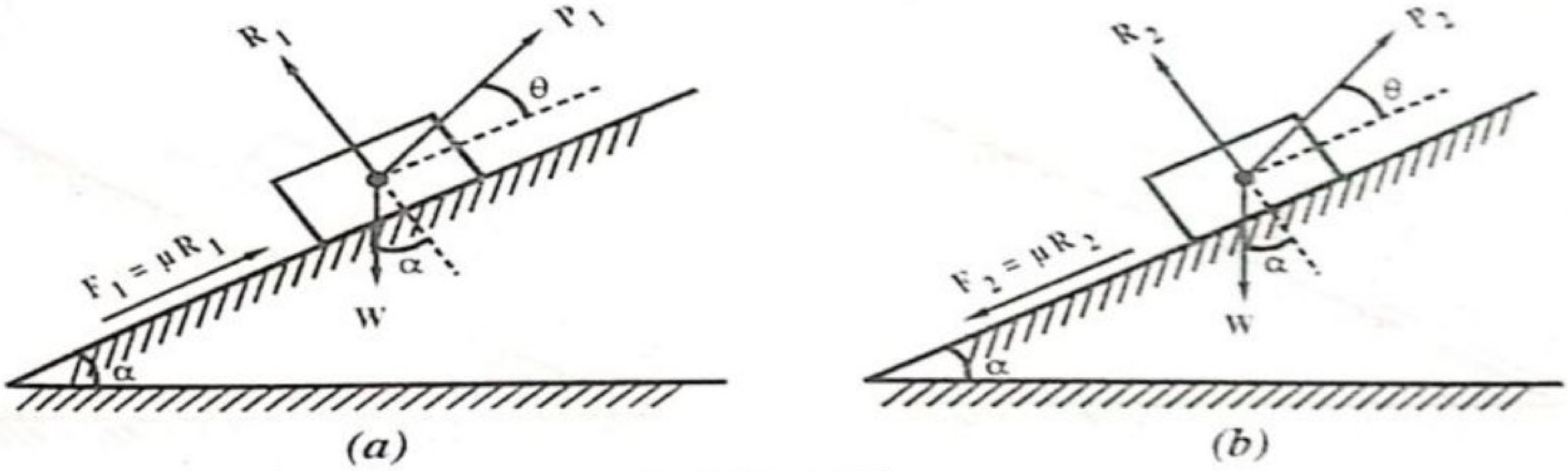
Now following two cases are possible –

- (a) Body is at the point of sliding downwards.
- (b) Body is at the point of sliding upwards.

(a) When Body is at the Point of Sliding Downwards –

Let P_1 = Force which will keep the body in equilibrium.

In this case frictional force ($F_1 = \mu R_1$) will act upward to resist the downward motion of body as shown in fig. 4.80 (a).



(a) (b)

Fig. 4.80

Resolving the forces along the plane,

$$P_1 \cos\theta + F_1 = W \sin\alpha$$

$$P_1 \cos\theta = W \sin\alpha - \mu R_1 \qquad \text{....(i)}$$

Now resolving the forces perpendicular to the plane,

$$R_1 = W \cos\alpha - P_1 \sin\theta$$

Substituting value of R_1 in equation (i), we get

$$P_1 \cos\theta = W \sin\alpha - \mu (W \cos\alpha - P_1 \sin\theta)$$

$$P_1(\cos\theta - \mu \sin\theta) = W (\sin\alpha - \mu \cos\alpha)$$

$$P_1 = W\frac{(\sin\alpha - \mu\cos\alpha)}{(\cos\theta - \mu\sin\theta)}$$

$$= W\frac{(\sin\alpha - \tan\phi\cos\alpha)}{(\cos\theta - \tan\phi\sin\theta)} \qquad (\because \mu = \tan\phi)$$

$$= W\frac{(\sin\alpha.\cos\phi - \sin\phi.\cos\alpha)}{(\cos\theta.\cos\phi - \sin\theta\sin\phi)}$$

$$= W\frac{\sin(\alpha - \phi)}{\cos(\theta + \phi)} \qquad \text{...(ii)}$$

(b) When Body is at the Point of Sliding Upwards – Refer fig. 4.80 (b). P_2 is the force required to keep the body in equilibrium. In this case

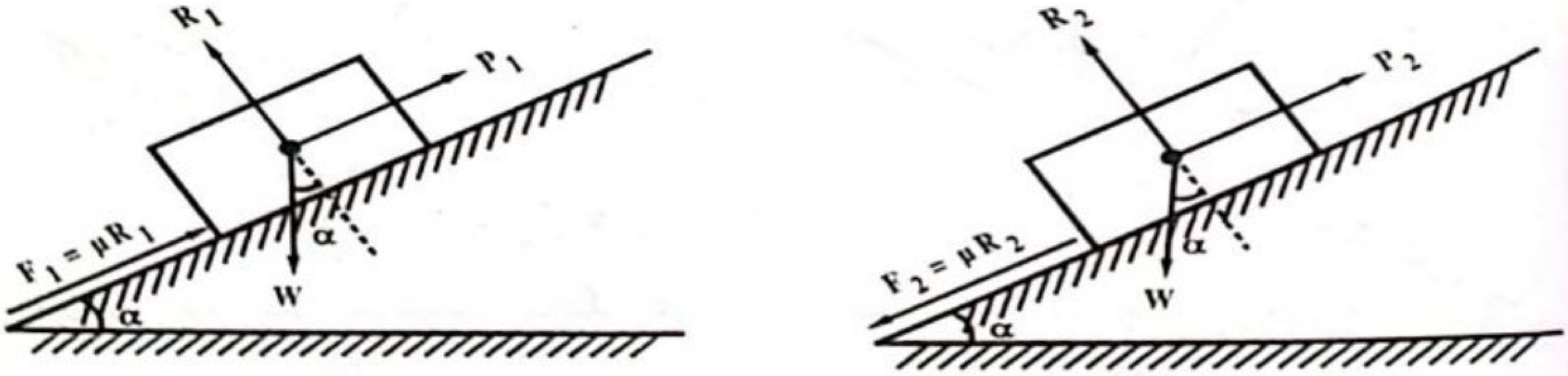
$$P_2 = W\frac{\sin(\alpha + \phi)}{\cos(\theta - \phi)} \qquad \text{...(iii)}$$

(ii) Force Applied Along the Inclined Plane – In this case $\theta = 0$, as shown in fig. 4.81 (a) and (b). Hence from equations (ii) and (iii), substituting $\theta = 0$, we get

$$P_1 = \frac{W\sin(\alpha - \phi)}{\cos\phi} \qquad \text{...(iv)}$$

and

$$P_2 = \frac{W\sin(\alpha + \phi)}{\cos\phi} \qquad \text{...(v)}$$



(a) *(b)*

Fig. 4.81

(iii) Force Applied Horizontally – A body resting on a rough inclined plane and subjected to horizontally applied force is shown in fig. 4.82.

(a) When Body is at the Point of Sliding Downwards – Refer fig. 4.82 (a).

Resolving the forces along the plane,

$$P_1\cos\alpha + F_1 = W\sin\alpha$$

$$P_1\cos\alpha + \mu R_1 = W\sin\alpha$$

$$P_1\cos\alpha = W\sin\alpha - \mu R_1 \qquad \text{...(vi)}$$

Now, resolving the forces perpendicular to the plane,

$$R_1 = W\cos\alpha + P_1\sin\alpha$$

Substituting value of R_1 in equation (vi), we get

$$P_1\cos\alpha = W\sin\alpha - \mu(W\cos\alpha + P_1\sin\alpha)$$

$$P_1(\cos\alpha + \mu\sin\alpha) = W(\sin\alpha - \mu\cos\alpha)$$

or

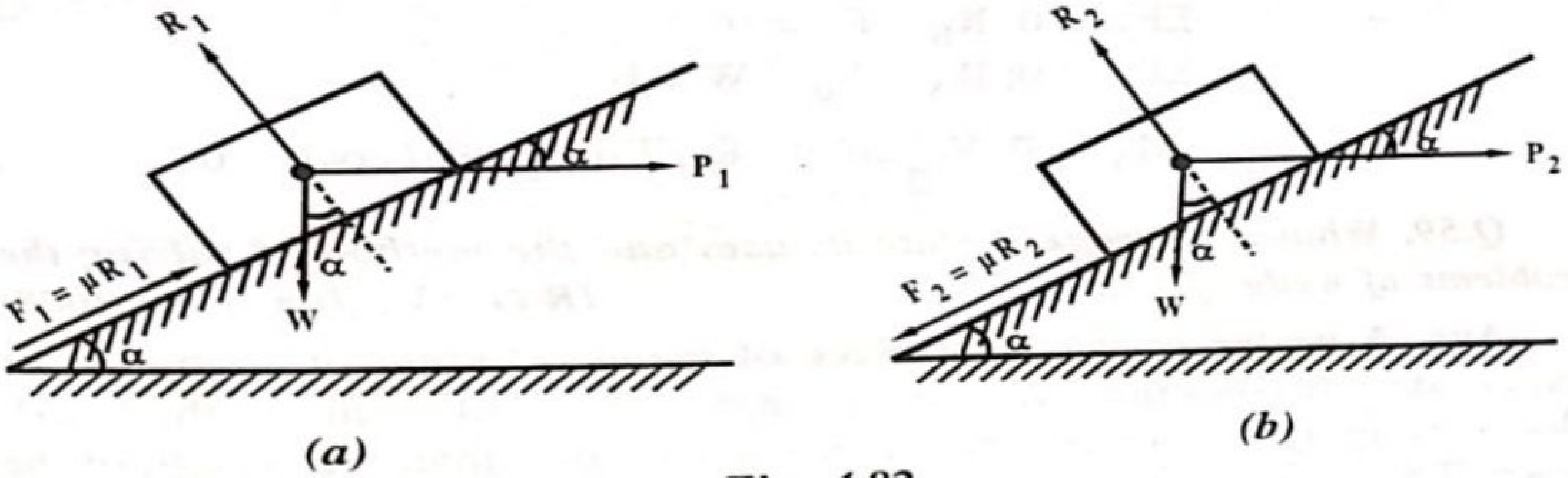
$$P_1 = W\frac{(\sin\alpha - \mu\cos\alpha)}{(\cos\alpha + \mu\sin\alpha)}$$

$$P_1 = W\frac{(\sin\alpha - \tan\phi\cos\alpha)}{(\cos\alpha + \tan\phi\sin\alpha)} \qquad (\because \mu = \tan\phi)$$

$$= W\frac{\sin(\alpha - \phi)}{\cos(\alpha - \phi)} = W\tan(\alpha - \phi) \qquad \text{...(vii)}$$

But, when $\phi > \alpha$ then

$$P_1 = W\tan(\phi - \alpha) \qquad \text{...(viii)}$$



(a) (b)

Fig. 4.82

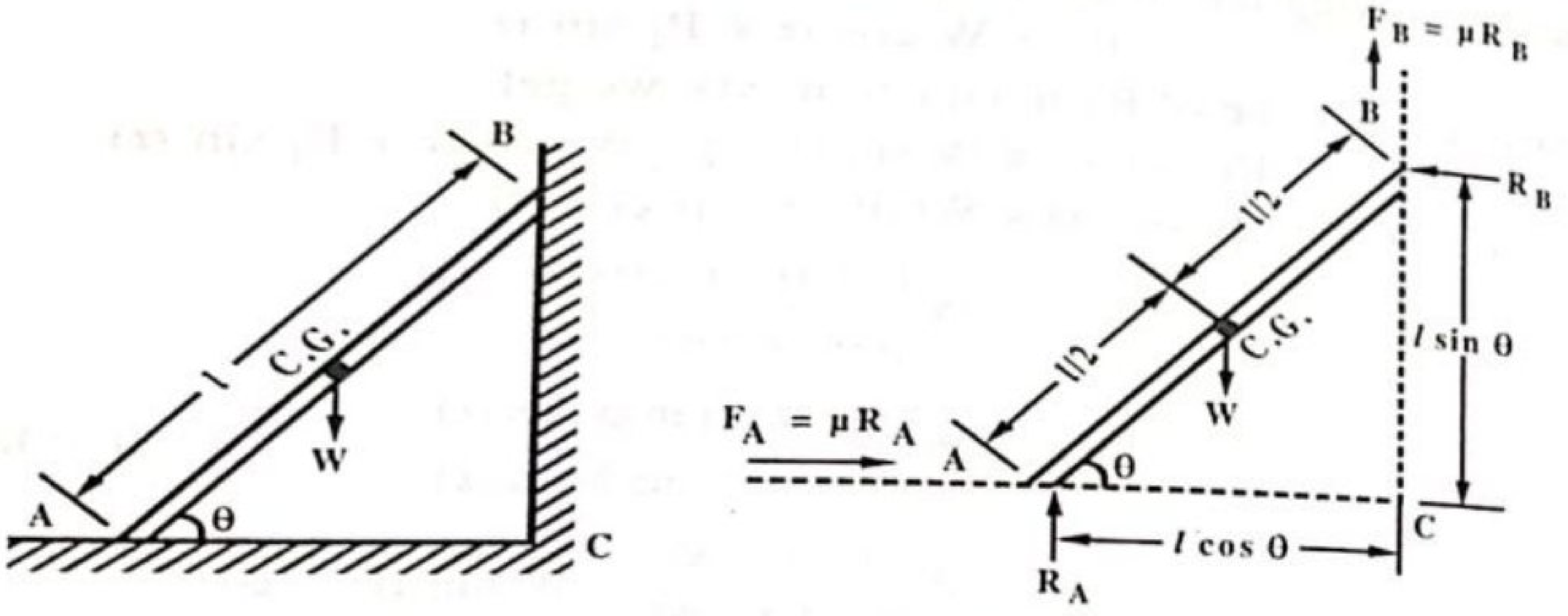
(b) When Body is at the Point of Sliding Upwards – Refer fig. 4.82 (b). In this case,

$$P_2 = W\tan(\alpha + \phi) \qquad \text{...(ix)}$$

Q.58. What is ladder friction ? Make free body diagram of a ladder placed on horizontal floor against a vertical wall. ***(R.G.P.V., Feb. 2007)***

Ans. The ladder is a device used for climbing or scaling on the roofs or walls. Its one end rests on ground, while other end leans against the vertical wall as shown in fig. 4.83 (a).

The upper end of ladder tends to slip downwards, due to its own weight or when some man stands on it. Thus, a frictional force acts between ladder and vertical wall in the upward direction. Similarly, the lower end of the ladder will tend to move away from the wall, thus force of friction will act in a direction towards the wall. The free body diagram of ladder showing various forces acting on it is shown in fig. 4.83 (b).



(a)

(b) Free Body Diagram

Fig. 4.83

Now for the equilibrium of the system,

$$\Sigma F_X = 0;\ R_B - F_A = 0$$

$$\Sigma F_Y = 0;\ R_A + F_B - W = 0$$

$$\Sigma M_A = 0; W.\frac{l}{2}\cos\theta - R_B.l\sin\theta - F_B l\cos\theta = 0$$

Q.59. What is a wedge ? State its uses and the method of solving the problems of wedge friction. ***(R.G.P.V., Jan./Feb. 2008)***

Ans. A wedge is usually a piece of metal or wood of triangular or trapezoidal cross-section. Wedges are generally used to move the heavy blocks by applying a force which is usually smaller than the weight of the block. They are also used for small adjustments in the position of heavy pieces of machinery.

Consider a triangular wedge ABC as shown in fig. 4.84 is used to lift the body DEFG. If force P is applied at the face BC of the wedge is just sufficient to lift the body, the wedge will move towards left and the load will move up. There will be sliding takes place along three planes AB, AC and DE. Hence, there will be three normal reactions on the planes AB, AC and DE, as shown in fig. 4.85 (a) and (b).

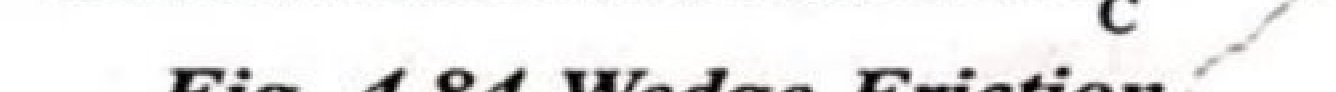
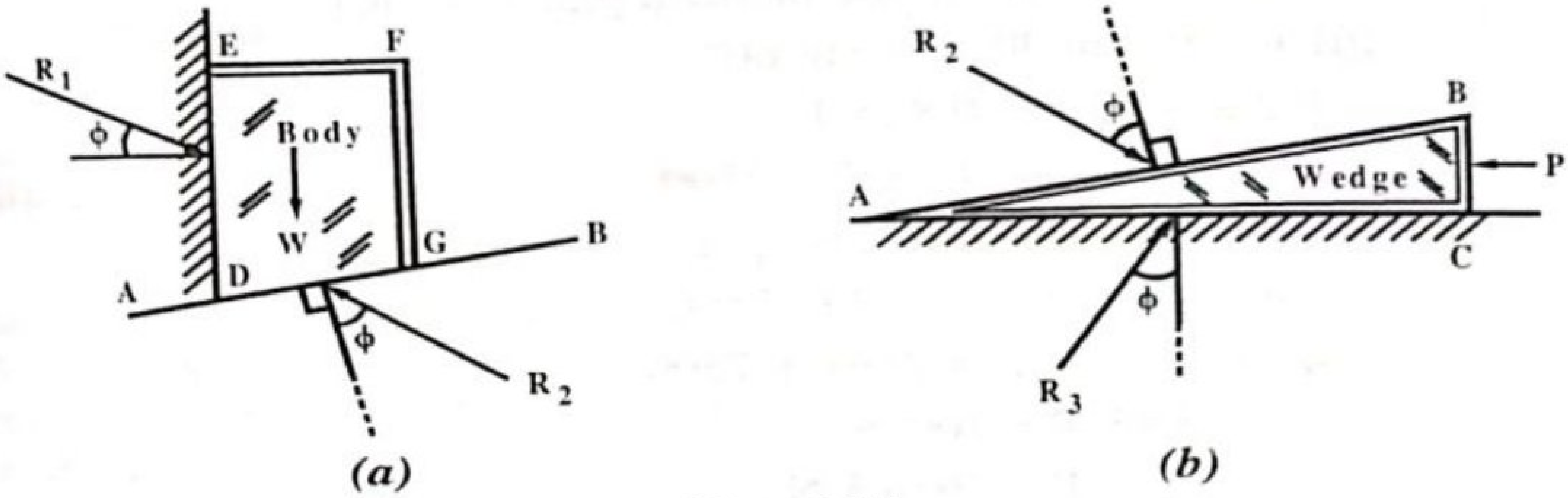


Fig. 4.84 Wedge Friction

The three reactions or the horizontal force (P) may now be found out by considering the equilibrium of wedge and block separately.



(a) (b)

Fig. 4.85

NUMERICAL PROBLEMS

Prob.19. A 3000 N block is placed on an inclined plane as shown in fig. 4.86. Find the maximum value of W for equilibrium if tipping does not occur. Assume coefficient of friction as 0.2.

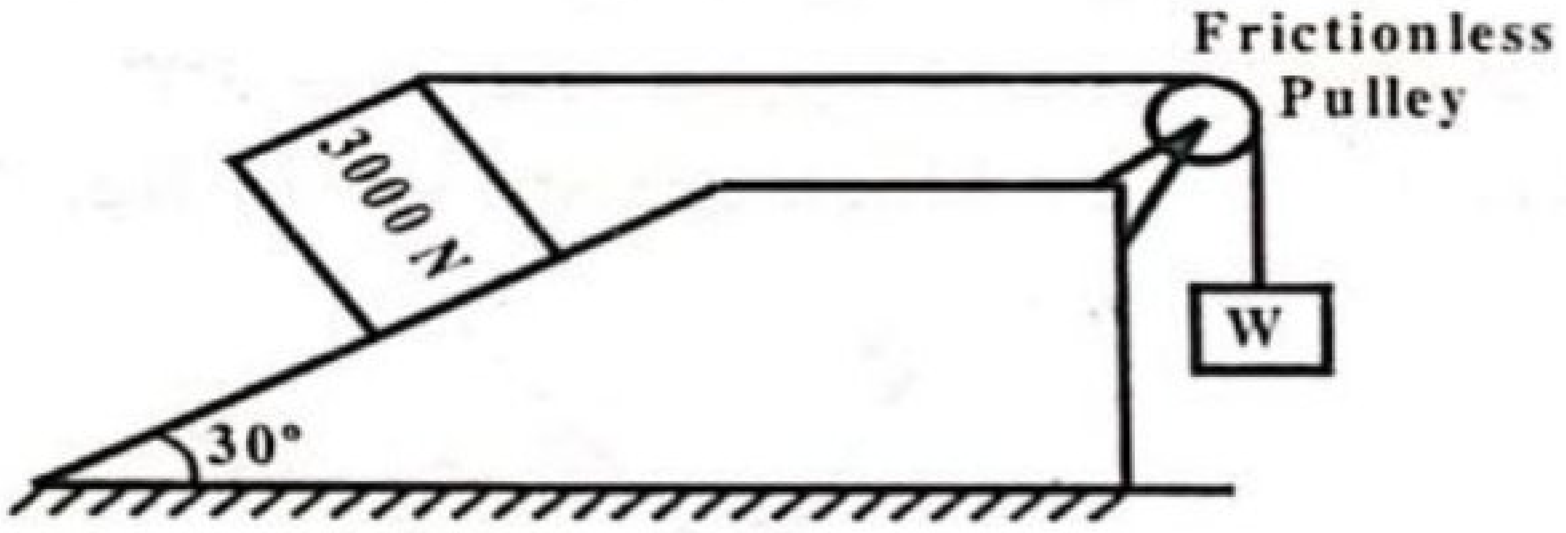
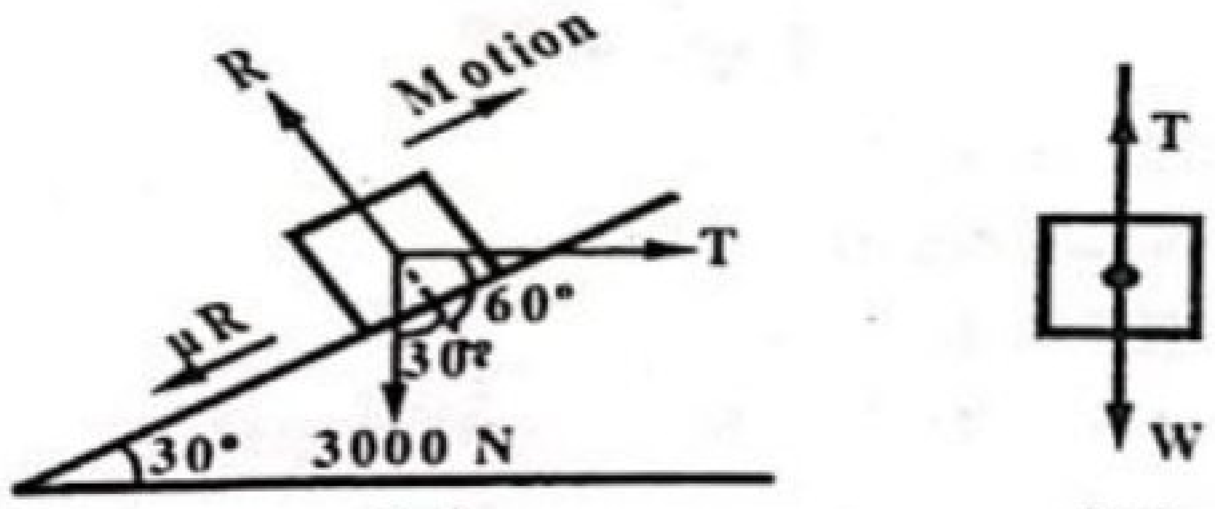


Fig. 4.86 *(R.G.P.V., Dec. 2011)*

Sol. For the equilibrium of the given arrangement, value of W will be maximum, when block of 3000 N is moving upward. In this case various forces acting on the blocks of weight 3000 N and W are shown in fig. 4.87 (a) and (b) respectively.



(a) (b)

Fig. 4.87

Cons idering equilibrium of block of 3000 N and resolving forces perpendicul ar to the inclined plane, we get

$$R = 3000 \cos 30° + T \cos 60°$$

$$R = 2598 + 0.5\ T \qquad \text{....(i)}$$

Now resolving forces along the inclined plane, we get

$$\mu R + 3000 \sin 30^\circ = T \sin 60^\circ$$

$$0.2\ R + 1500 = 0.866\ T$$

or $$R = 4.33\ T - 7500 \quad ....(ii)$$

Equating equations (i) and (ii), we get

$$2598 + 0.5\ T = 4.33\ T - 7500$$

or $$4.33\ T - 0.5\ T = 2598 + 7500$$

$$3.83\ T = 10098$$

$\therefore$ $$T = 2636.5\ N$$

For equilibrium of the weight W,

$$W = T = \mathbf{2636.5\ N}$$

Ans.

Prob.20. A block of 300 N weight is resting on a plane inclined at 30° to the horizontal, the coefficient of friction between the block and the plane is 0.4. A force, inclined at an angle of 30° is acting on the block. Find the minimum force to move the block upwards. ***(R.G.P.V., Dec. 2013)***

Sol. Given, $W = 300$ N, $\alpha = 30^\circ$, $\mu = 0.4$, $\theta = 30^\circ$.

Various forces acting on the block are shown in fig. 4.88

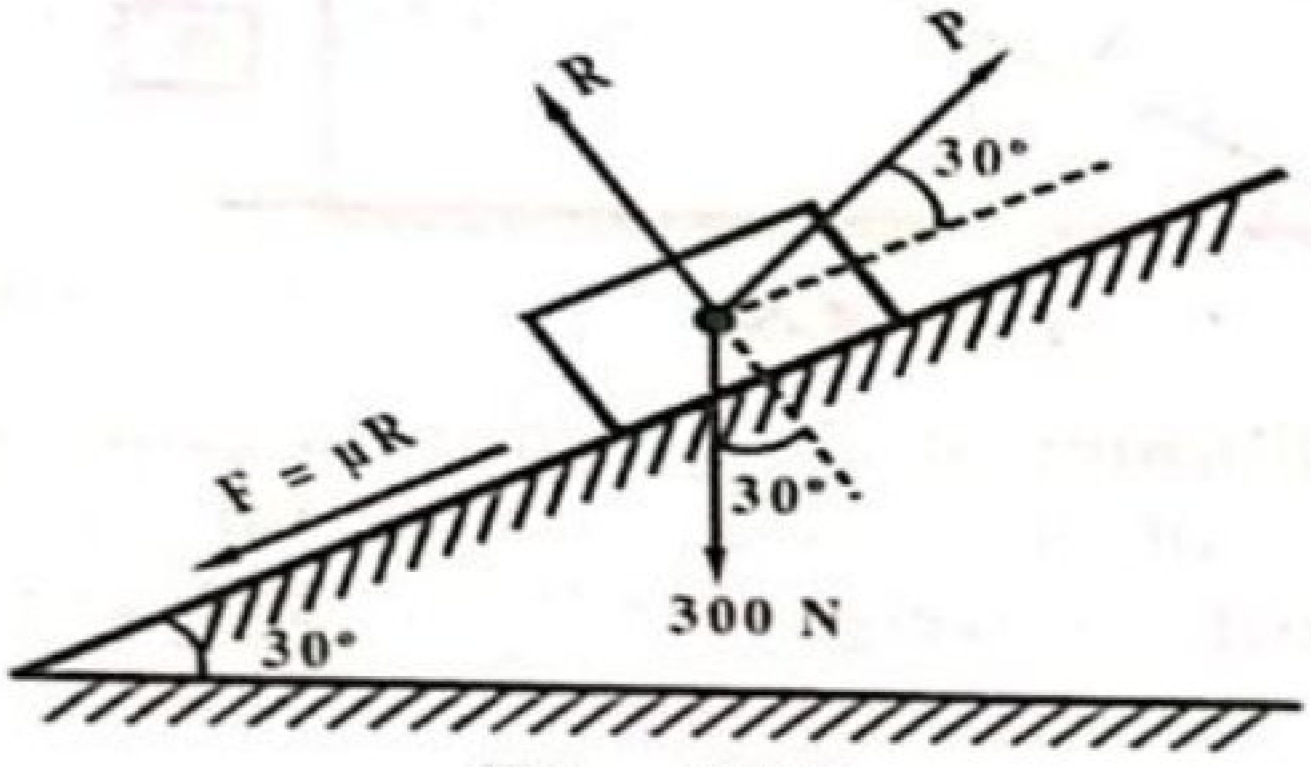


Fig. 4.88

Let P = Force acting on the block.

Resolving the forces along the plane,

$$P \cos 30^\circ = W \sin 30^\circ + F$$

$$P \times 0.866 = 300 \times 0.5 + 0.4 \times R \quad (\because F = \mu R)$$

$$0.866\ P = 150 + 0.4\ R$$

or $$0.4\ R = 0.866\ P - 150$$

$\therefore$ $$R = 2.165\ P - 375 \quad ...(i)$$

Now, resolving the forces perpendicular to the plane,

$$R + P \sin 30^\circ = W \cos 30^\circ$$

$$R + 0.5\ P = 300 \times 0.866 = 259.8$$

Substituting the value of R from equation (i),

$$2.165\ P - 375 + 0.5\ P = 259.8$$

or
$$2.665\ P = 634.8$$

$\therefore$
$$P = \mathbf{238.2\ N}$$
Ans.

Prob.21. A 4 m ladder weighing 200 N is placed against a vertical wall as shown in fig. 4.89. As a man weighing 800 N reaches a point 2.7 m from A, the ladder is about to slip. Assuming that the coefficient of friction between the ladder and the wall is 0.2, determine coefficient of friction between the ladder and the floor.

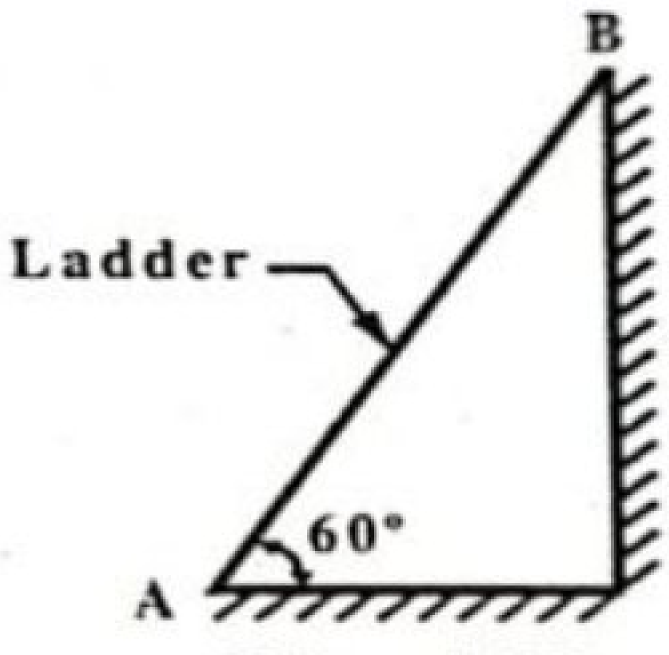


Fig. 4.89

(R.G.P.V., June 2012)

Sol. Given, l = 4 m, weight of ladder, W = 200 N, $\theta = 60°$, weight of man, P = 800 N, $\mu_B = 0.2$.

Let μ_A = Coefficient of friction between the ladder and the floor.

Let R_A and R_B be the reactions at points A and B respectively.

Various forces acting on the ladder are shown in fig. 4.90

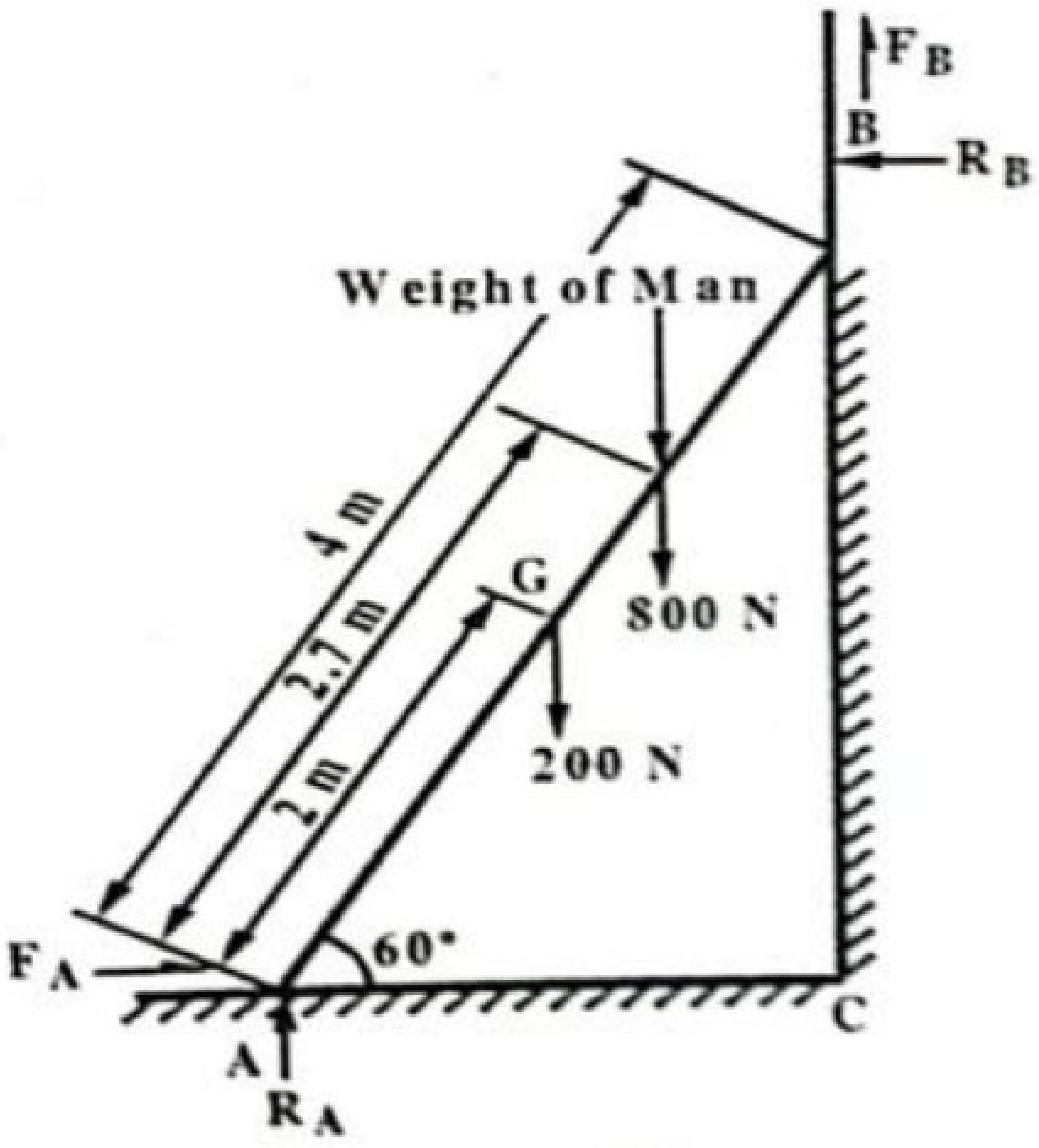


Fig. 4.90

Taking moments of all forces about point A, we get

$$R_B \times 4 \sin 60° + F_B \times 4 \cos 60° = 800 \times 2.7 \cos 60° + 200 \times \frac{4}{2} \cos 60°$$

$$R_B \times 4 \times \frac{\sqrt{3}}{2} + 0.2\ R_B \times 4 \times 0.5 = 800 \times 2.7 \times 0.5 + 200 \times 2 \times 0.5$$

$$2\sqrt{3}\ R_B + 0.4\ R_B = 1080 + 200$$

$$3.864\ R_B = 1280$$

$$\therefore \quad R_B = 331.3\ \text{N}$$

Resolving forces vertically, we get

$$R_A + F_B = W + P$$

$$R_A + \mu_B R_B = W + P$$

$$R_A + 0.2 \times 331.3 = 200 + 800$$

or $$R_A = 1000 - (0.2 \times 331.3) = 933.7\ \text{N}$$

Now resolving forces horizontally, we get

$$F_A = R_B$$

$$\mu_A R_A = R_B$$

$$\mu_A \times 933.7 = 331.3$$

$$\mu_A = \mathbf{0.355}$$

Ans.

■■

UNIT 5

CENTRE OF GRAVITY AND MOMENT OF INERTIA

CENTROID AND CENTRE OF GRAVITY

Q.1. What do you understand by centre of gravity ?

(R.G.P.V., Dec. 2015)

Ans. ***Centre of gravity*** of a body may be defined as the point at which whole weight of the body assumed to be concentrated. A body can have only one centre of gravity, irrespective of all its orientations. A body may be considered to be composed of number of particles. These particles are attracted towards the centre of the earth due to gravitational force. Since size of the body is very small as compared to the radius of earth, therefore all such particles of a body can be assumed at same distance from the earth. Thus, all the forces acting on particles of body forms a system of parallel forces. The point through which the resultant of all such parallel forces passes, in all positions of the body, is called as the centre of gravity (C.G.).

2 ②

Q.2. Define centroid.

Ans. The plane areas such as triangle, quadrilateral, circle, etc., have only areas, but no mass. The entire area of such plane figures may assumed to be concentrated at a point, which is known as ***centroid*** of the area.

Q.3. Distinguish between centre of gravity and centroid.

(R.G.P.V., June 2015)

Ans. The basic difference between centroid and centre of gravity is as follows –

Centroid is used for geometrical figures like line, areas and volumes and depends only on the geometry of the body. While centre of gravity is used for physical bodies like wires, plates and solids and depends upon the physical properties of the body.

However for plane areas, the centroid and centre of gravity are the same and can be used synonymously.

Q.4. How will you locate the centroid of a plane lamina ? Explain with figure. ***(R.G.P.V., Feb. 2007, March/April 2010)***

Ans. Consider a plane area as shown in fig. 5.1. whose centroid has to be determined. Let A be the whole area of given figure. It can considered to be composed of a number of small areas a_1, a_2, a_3, a_4....etc.

$$A = a_1 + a_2 + a_3 + a_4 + \ldots\ldots$$

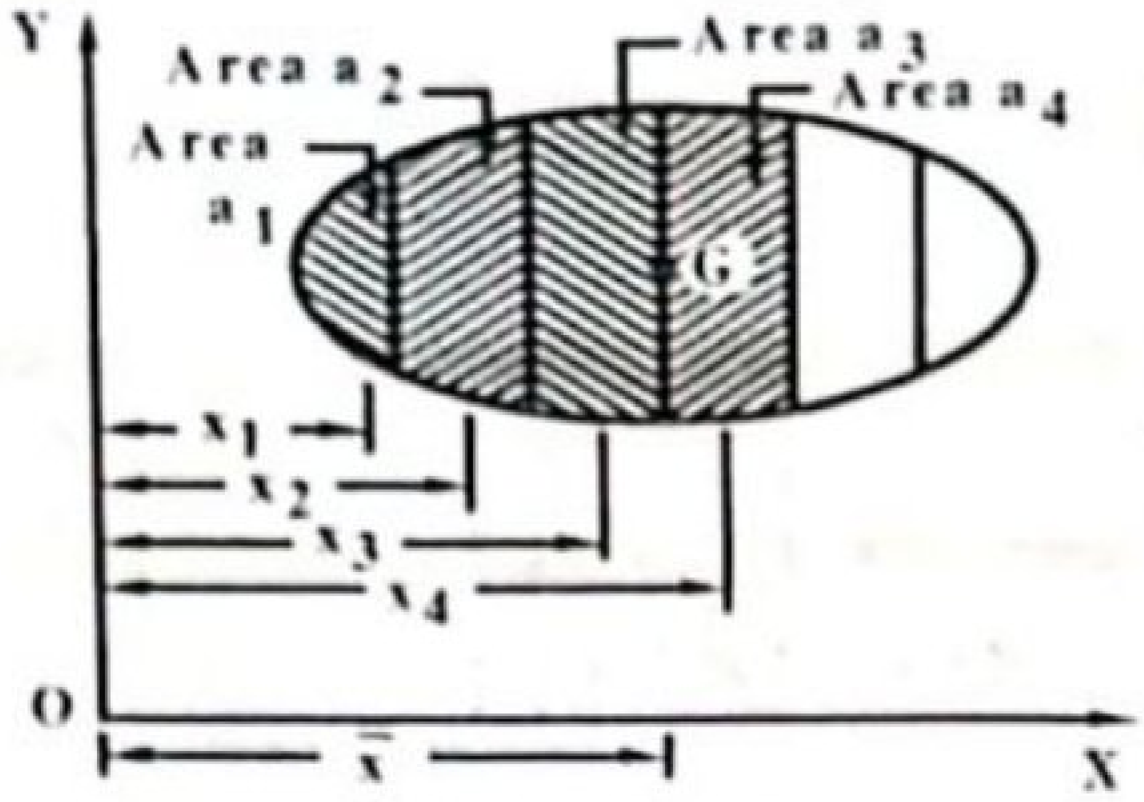


Fig. 5.1

Let OX and OY be the reference axes. Also let

x_1, x_2, x_3, x_4 ..... = The distances of centroid of areas a_1, a_2, a_3, a_4...from axis OY respectively

y_1, y_2, y_3, y_4 .... = The distances of centroid of areas a_1, a_2, a_3, a_4...from axis OX respectively.

Thus, moments of all small areas about axis OY

$$= a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + \ldots.. \quad \text{....(i)}$$

Now if G be the centroid (or centre of gravity) of total area A, whose distance from the axis OY is $\bar{x}$, then moment of total area about OY

$$= A\bar{x} \quad \text{....(ii)}$$

The moment of all small areas about the axis OY must be equal to the moment of total area about the same axis. Hence equating equations (i) and (ii),

$$A\bar{x} = a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + \ldots.$$

or

$$\bar{x} = \frac{a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4 + \ldots..}{A} \quad \text{....(iii)}$$

Similarly,

$$\bar{y} = \frac{a_1y_1 + a_2y_2 + a_3y_3 + a_4y_4 + \ldots..}{A} \quad \text{....(iv)}$$

Equations (iii) and (iv) give the location of centroid of plane figure.

Following points should be kept in mind while determining the location of centroid of plane areas –

(i) Axis of reference, of plane figures, is generally taken as the lowest line of the figure for calculating $\bar{y}$ and the left line of the figure for calculating $\bar{x}$.

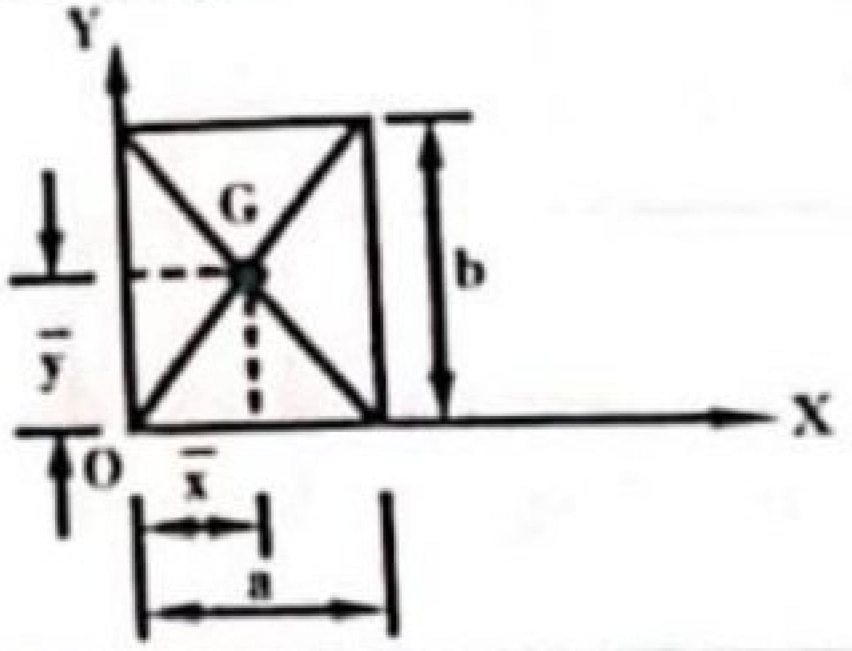
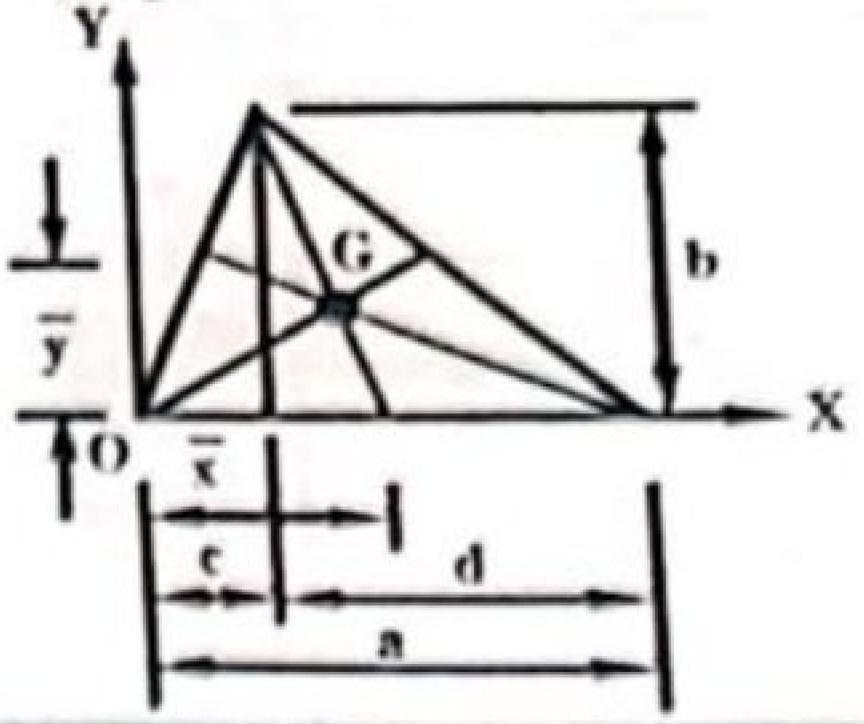
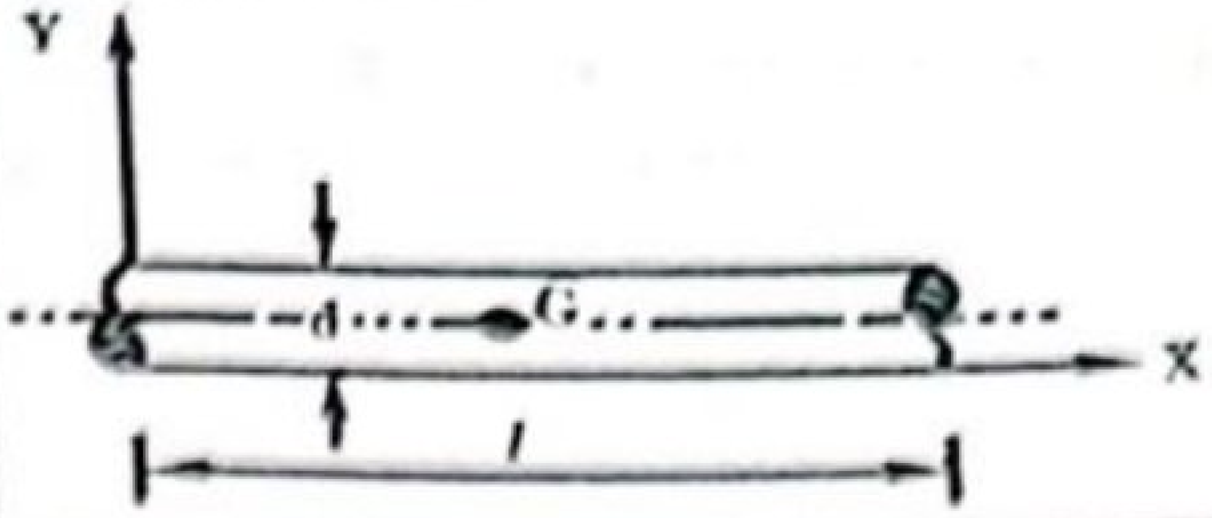
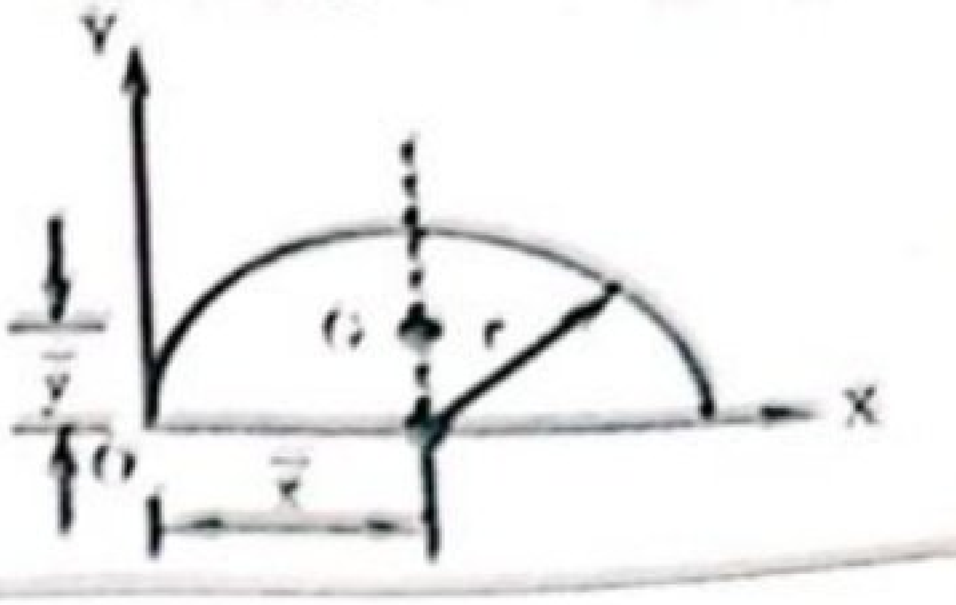
(ii) Values of x_1, x_2, x_3, x_4 .... and y_1, y_2, y_3, y_4 .... should be measured on same side of axis of reference. If, however, the figure is on both sides of the axis of reference, then the distances in one direction are taken as positive and those in the opposite direction must be taken negative.

(iii) If given section is symmetrical about XX-axis or YY-axis, then we only have to calculate either $\bar{x}$ or $\bar{y}$, because centroid or C.G. of the section lies on the axis of symmetry.

① ⓐ ***Q.5. Give the position of centroid of the following standard sections – (i) Rectangle (ii) Triangle (iii) Uniform rod (iv) Semi-circle.***
(R.G.P.V., Jan./Feb. 2008)

Ans. Refer table 5.1.

Table 5.1

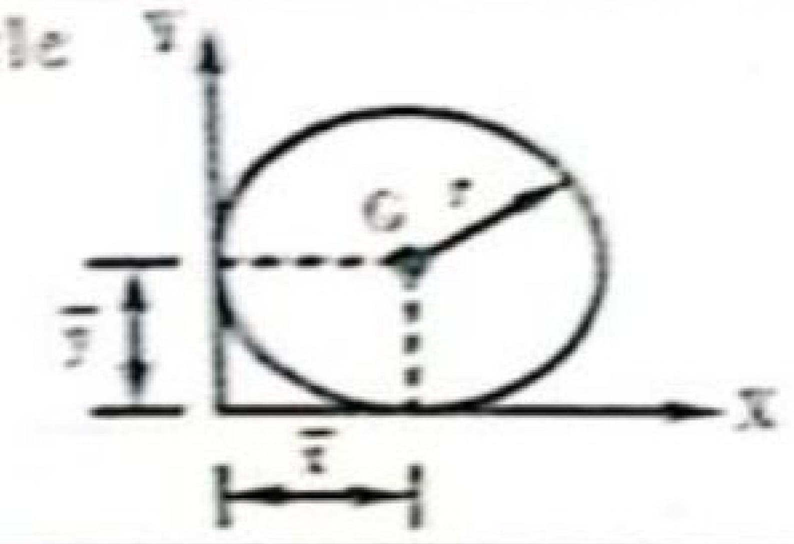
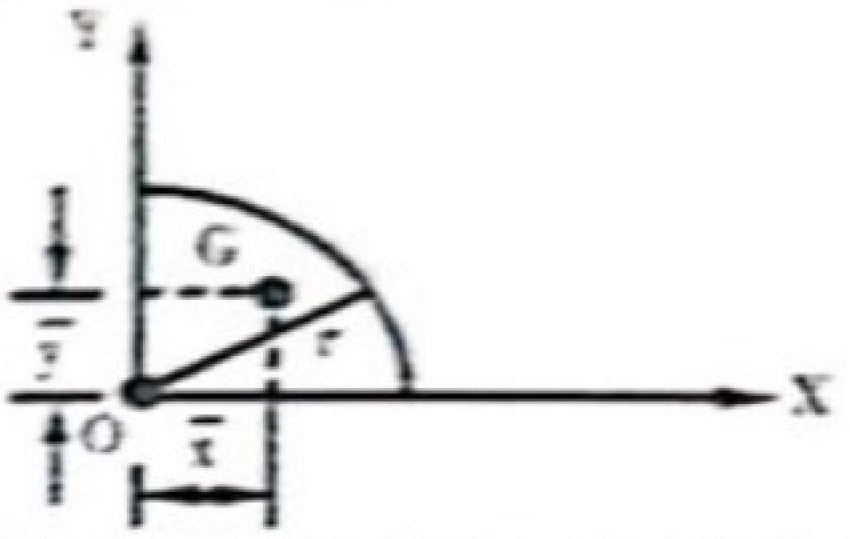
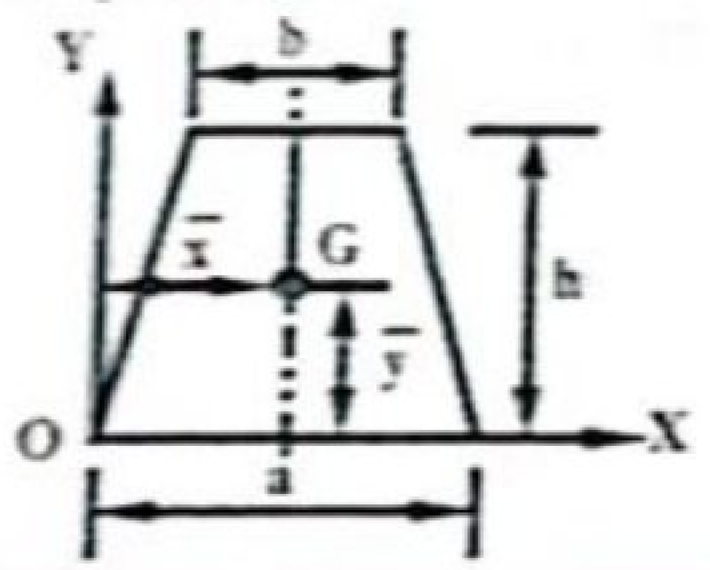
S. No.	*Section*	*Area*	*Centroid*		
			Position	*Co-ordinates*	
				$\bar{x}$	$\bar{y}$
(i)	Rectangle 	ab	At the intersection of its diagonals. This is the middle point of length as well as the breadth of the rectangle.	$\frac{a}{2}$	$\frac{b}{2}$
(ii)	Triangle  Y G b $\bar{y}$ O $\bar{x}$ c d a X	$\frac{ab}{2}$	At the intersection of its medians.	$\frac{c+a}{3}$	$\frac{b}{3}$
(iii)	Uniform rod 	Volume $= \frac{\pi}{4} d^2 l$	At its middle point.	$\frac{l}{2}$	$\frac{d}{2}$
(iv)	Semi-circle 	$\frac{\pi r^2}{2}$	At a distance $4r/3\pi$ from its base measured along the vertical radius	r	$\frac{4r}{3\pi}$

Q.6. Give the expression of area and position of centroid of following standard sections –

(i) Circle
(ii) Quarter circle
(iii) Trapezium.

Ans. Refer table 5.2.

Table 5.2

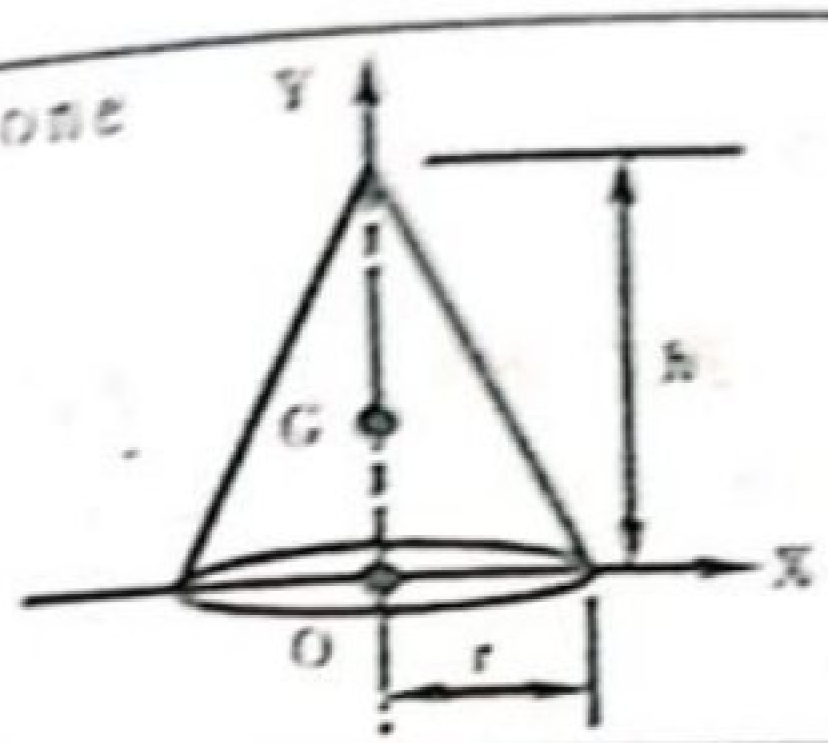
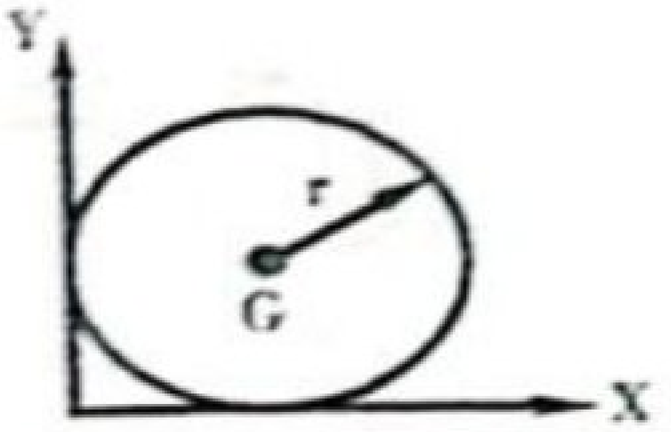
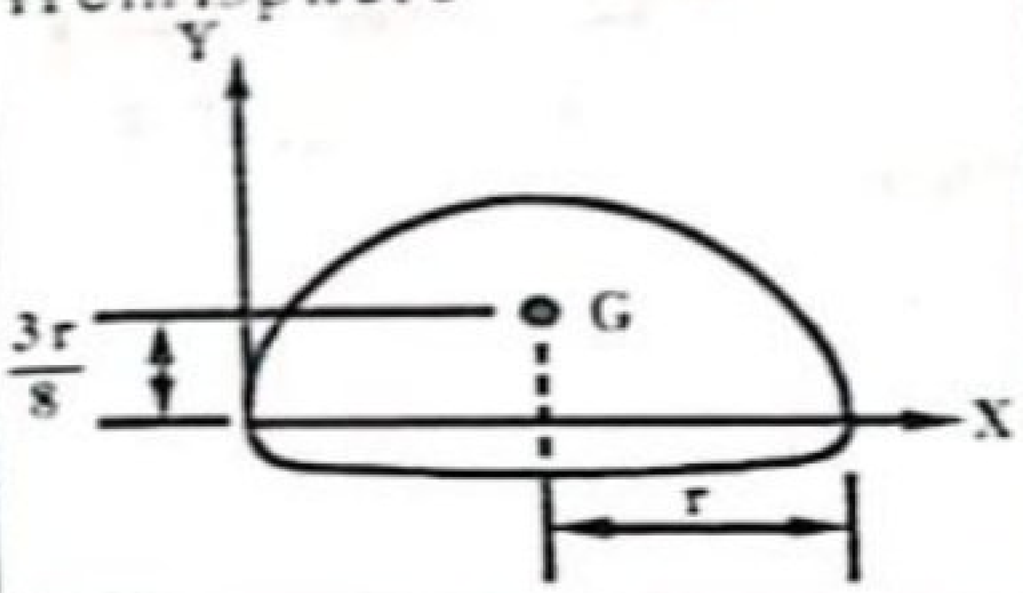
S. No.	Section	Area	Centroid		
			Position	Co-ordinates	
				$\bar{x}$	$\bar{y}$
(i)	Circle 	πr^2	Centre of circle	r	r
(ii)	Quarter circle 	$\frac{\pi r^2}{4}$		$\frac{4r}{3\pi}$	$\frac{4r}{3\pi}$
(iii)	Trapezium 	$\left(\frac{a+b}{2}\right)h$	For a trapezium with parallel sides a and b centroid lies at a distance of $\left(\frac{a+b}{2}\right)\frac{h}{3}$ measured from the side a.	$\frac{a}{2}$	$\left(\frac{a+2b}{a+b}\right)\frac{h}{3}$

Q.7. Give the expression of volume and position of centre of gravity of following solids –

(i) Cone
(ii) Sphere
(iii) Hemisphere.

Ans. Refer table 5.3.

Table 5.3

S. No.	Section	Volume	Centroid		
			Position	Co-ordinates	
				x	y
(i)	Cone 	Volume $= \frac{\pi}{3} r^2 h$	At a distance h/4 from its base, measured along the vertial axis.	0	$\frac{h}{4}$
(ii)	Sphere 	Volume $= \frac{4}{3}\pi r^3$	At a distance r from every point (= radius of sphere)	r	r
(iii)	Hemisphere 	Volume $= \frac{4}{6}\pi r^3$	At a distance 3r/8 from its base measured along the vertical radius.	r	$\frac{3r}{8}$

Q.8. What remains the position of centroid/C.G. of following laminas ?

- ***(i) Rectangular section***
- ***(ii) Triangular section***
- ***(iii) Circular section***
- ***(iv) Semi-circle***
- ***(v) Hemisphere***
- ***(vi) Uniform rod.***

(R.G.P.V., Dec. 2014)

Ans. Refer Q.5, Q.6 and Q.7.

NUMERICAL PROBLEMS

#①ⓑ

Prob.1. Locate the centroid of the area shown in fig. 5.2. All dimensions are in mm.

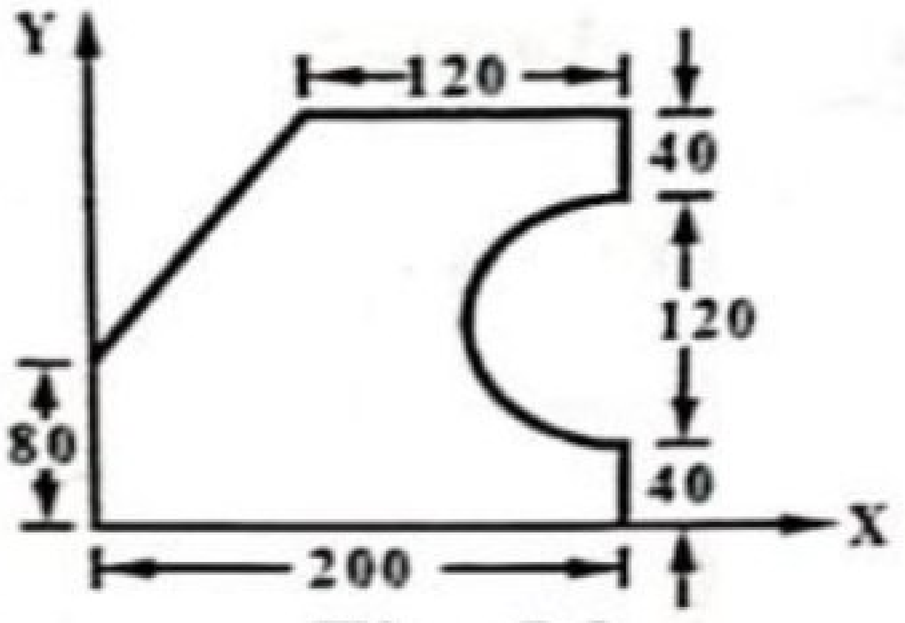


Fig. 5.2

(R.G.P.V., Jan./Feb. 2008)

Sol. The centroid of the section can be determined by considering it as a square of side 200 mm, out of which a right angle triangle and a semi-circle has been cut as shown in fig. 5.3. Let us take X and Y axes as reference axes.

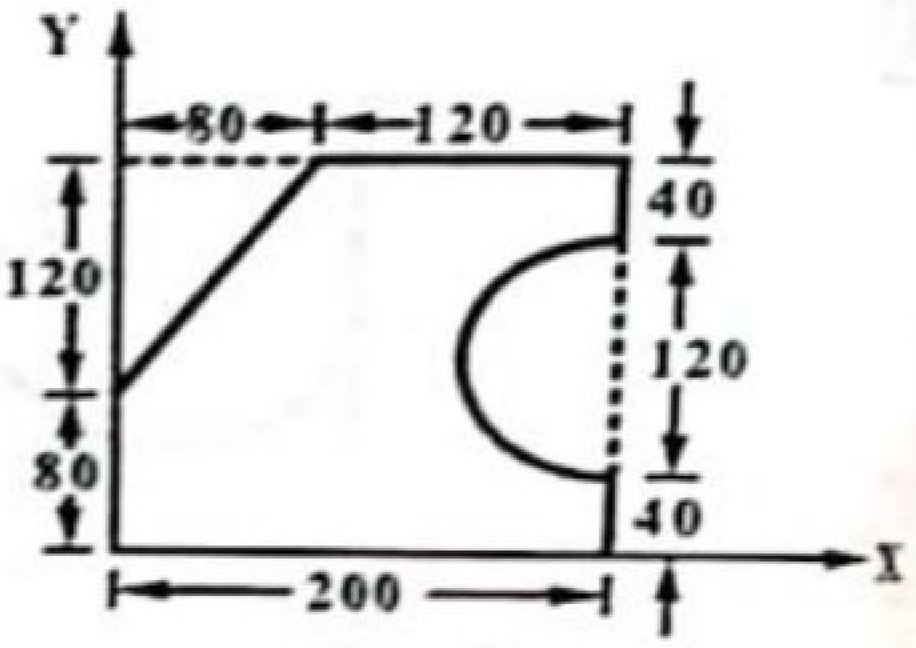


Fig. 5.3

(i) Square

Area, $a_1 = (200)^2 = 40000 \text{ mm}^2$

$$x_1 = y_1 = \frac{200}{2} = 100 \text{ mm}$$

(ii) Triangle

Area, $a_2 = \frac{1}{2} \times 80 \times 120 = 4800 \text{ mm}^2$

$$x_2 = \frac{80}{3}, y_2 = 80 + \frac{2 \times 120}{3} = 160 \text{ mm}$$

(iii) Semi-circle

Area, $a_3 = \frac{\pi r^2}{2} = \frac{\pi}{2} \times (60)^2 = 5655 \text{ mm}^2$

$$x_3 = 200 - \frac{4r}{3\pi} = 200 - \frac{4 \times 60}{3\pi} = 174.5 \text{ mm}$$

$$y_3 = 40 + 60 = 100 \text{ mm}$$

Thus, $\bar{x} = \frac{a_1x_1 - a_2x_2 - a_3x_3}{a_1 - a_2 - a_3}$

$$= \frac{(40000 \times 100) - \left(4800 \times \frac{80}{3}\right) - (5655 \times 174.5)}{40000 - 4800 - 5655} = \mathbf{97.65 \text{ mm}} \text{ **Ans.**}$$

and $\bar{y} = \frac{a_1y_1 - a_2y_2 - a_3y_3}{a_1 - a_2 - a_3}$

$$= \frac{(40000 \times 100) - (4800 \times 160) - (5655 \times 100)}{40000 - 4800 - 5655} = \mathbf{90.25 \text{ mm}} \text{ **Ans.**}$$

Prob.2. Determine the centroid of the sector of the circle using two different approaches (fig. 5.4).

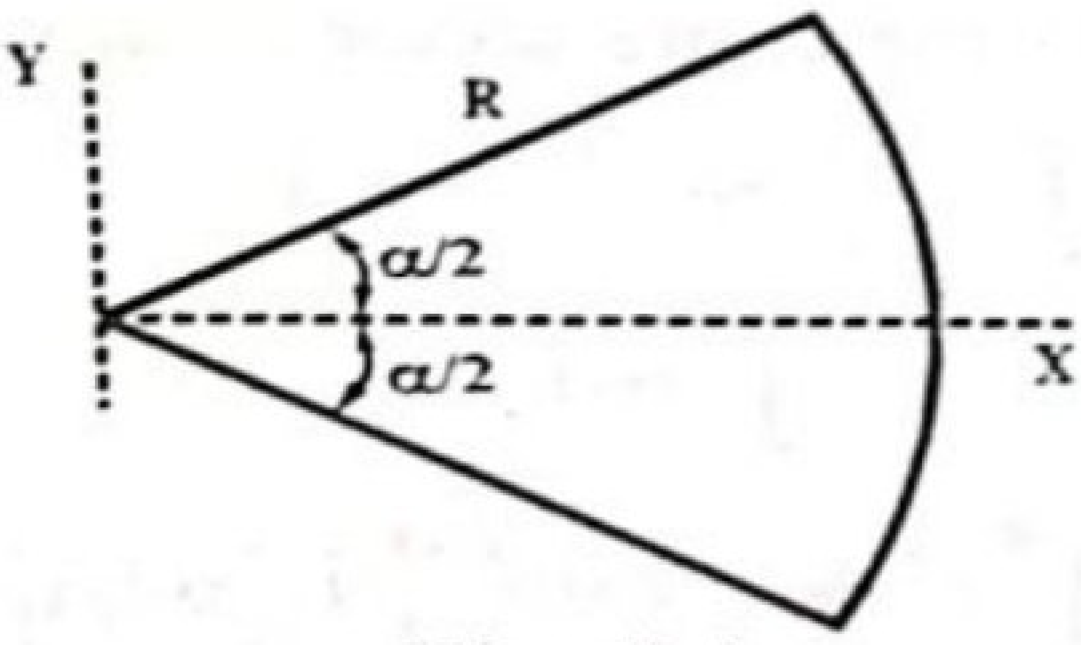


Fig. 5.4

(R.G.P.V., June 2014)

Sol. **Ist Method –** As given sector is symmetrical about X-axis, therefore,

$$\bar{y} = \mathbf{0} \qquad \textbf{Ans.}$$

To determine $\bar{x}$ let us divide the sector into a large number of triangular elements, each of altitude R and base Rdθ as shown in fig. 5.5. The area of dA of this triangular element is given by,

$$dA = \frac{1}{2} R.R\, d\theta = \frac{1}{2} R^2 d\theta$$

If C.G. of the triangular element lies at G, then

$$OG = \frac{2}{3} \times R$$

Distance of C.G. of area dA from y-axis,

$$x = OG \cos\theta$$

$$= \frac{2}{3} R \cos\theta$$

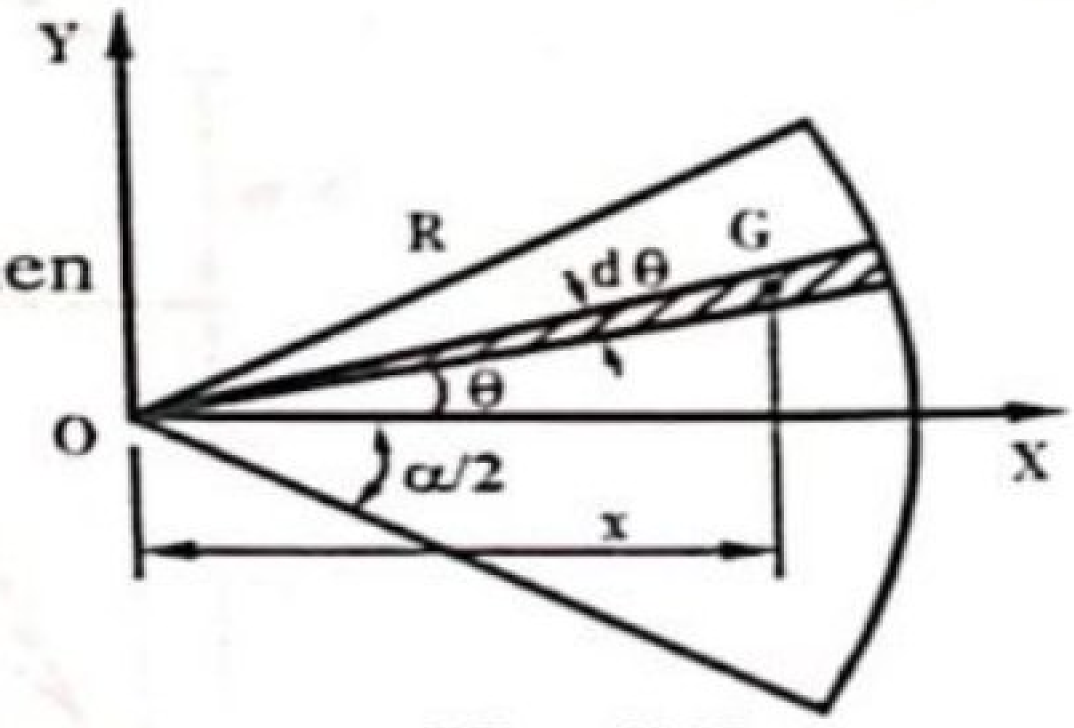


Fig. 5.5

Distance of C.G. of entire sector from y-axis will be given by

$$\bar{x} = \frac{\int x dA}{\int dA} = \frac{2\int_0^{\alpha/2}\left(\frac{2}{3}R\cos\theta\right).\left(\frac{1}{2}R^2 d\theta\right)}{2\int_0^{\alpha/2}\frac{1}{2}R^2 d\theta} = \frac{\frac{R^3}{3}\int_0^{\alpha/2}\cos\theta\, d\theta}{\frac{R^2}{2}\int_0^{\alpha/2} d\theta} = \frac{2R}{3}.\frac{[\sin\theta]_0^{\alpha/2}}{[\theta]_0^{\alpha/2}}$$

$$= \frac{2R}{3}.\frac{\sin(\alpha/2)}{\alpha/2} = \frac{\mathbf{4R}}{\mathbf{3\alpha}}\mathbf{\sin(\alpha/2)} \qquad \textbf{Ans.}$$

2nd Method – Consider an elementary arc of thickness dr at a distance r from O as shown in fig. 5.6. Area of this elementary arc will be

$$dA = \alpha.\, r.dr$$

Distance of C.G. of this elementary arc from y-axis will be

$$x = \frac{2r}{\alpha}.\sin\frac{\alpha}{2}$$

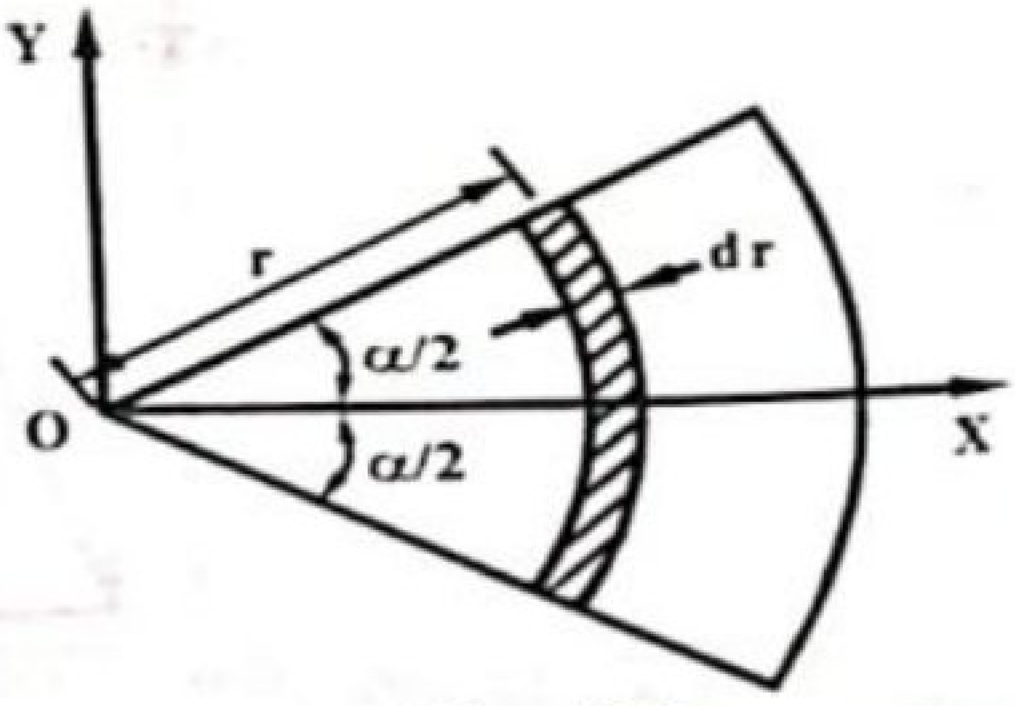


Fig. 5.6

Distance of centroid of the entire sector from y-axis will be

$$\bar{x} = \frac{\int x\,dA}{\int dA} = \frac{\int_0^R \left(\frac{2r}{\alpha}.\sin\frac{\alpha}{2}\right).(\alpha r\,dr)}{\int_0^R \alpha r\,dr}$$

$$= \frac{2\sin\left(\frac{\alpha}{2}\right)}{\alpha}.\frac{\int_0^R r^2\,dr}{\int_0^R r\,dr} = \frac{2\sin\left(\frac{\alpha}{2}\right)}{\alpha}.\frac{\left[R^3/3\right]}{\left[R^2/2\right]} = \frac{\mathbf{4R}}{\mathbf{3\alpha}}\,\mathbf{sin(\alpha/2)} \qquad \text{Ans.}$$

Since sector is symmetrical about x-axis, therefore

$$\bar{y} = \mathbf{0} \qquad \text{Ans.}$$

Prob.3. Determine the centroid of the section of the concrete dam shown in fig. 5.7.

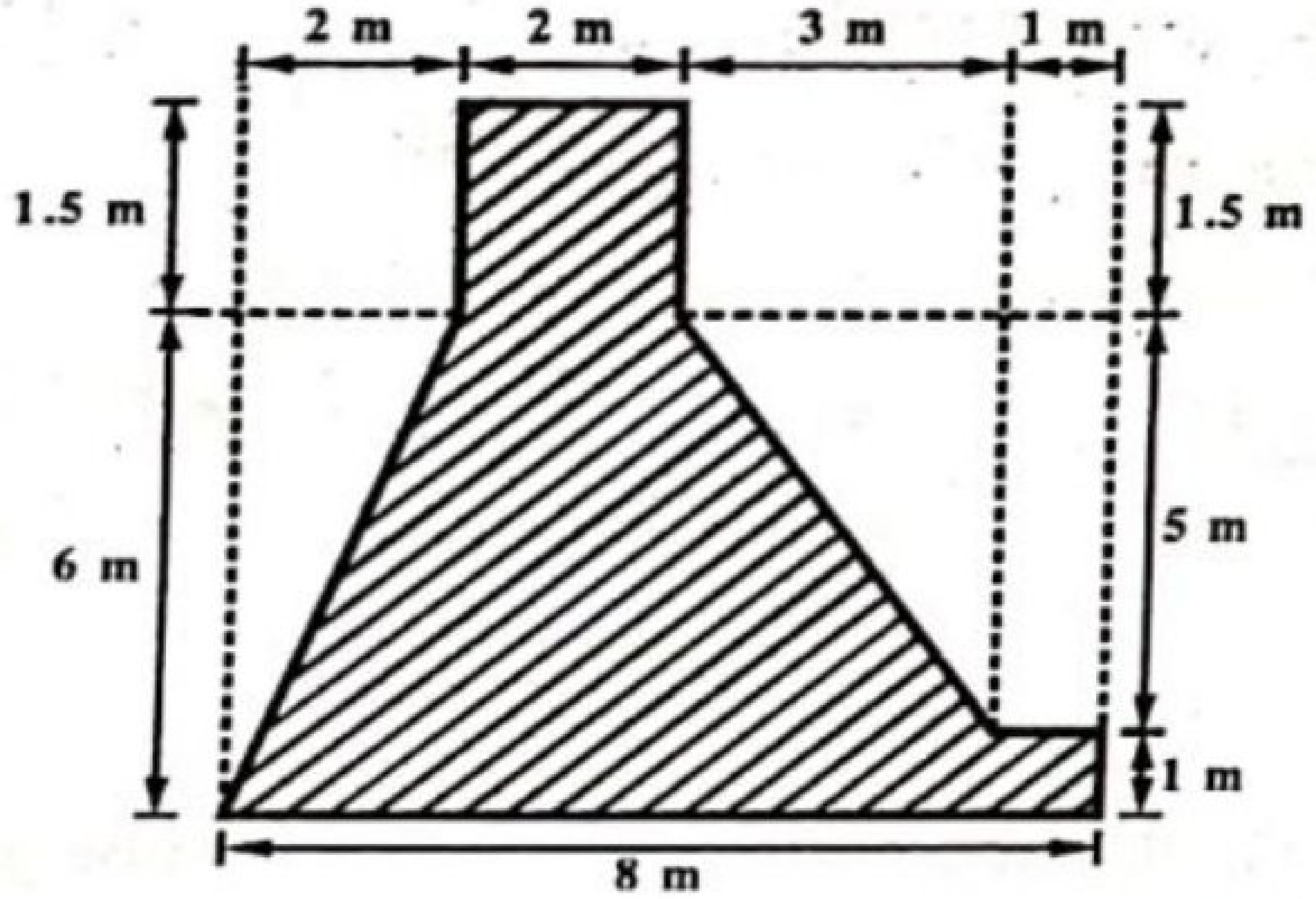


Fig. 5.7 *(R.G.P.V., Dec. 2011)*

Sol. The given section of dam can be splitted into 4 sub-sections as shown in fig. 5.8.

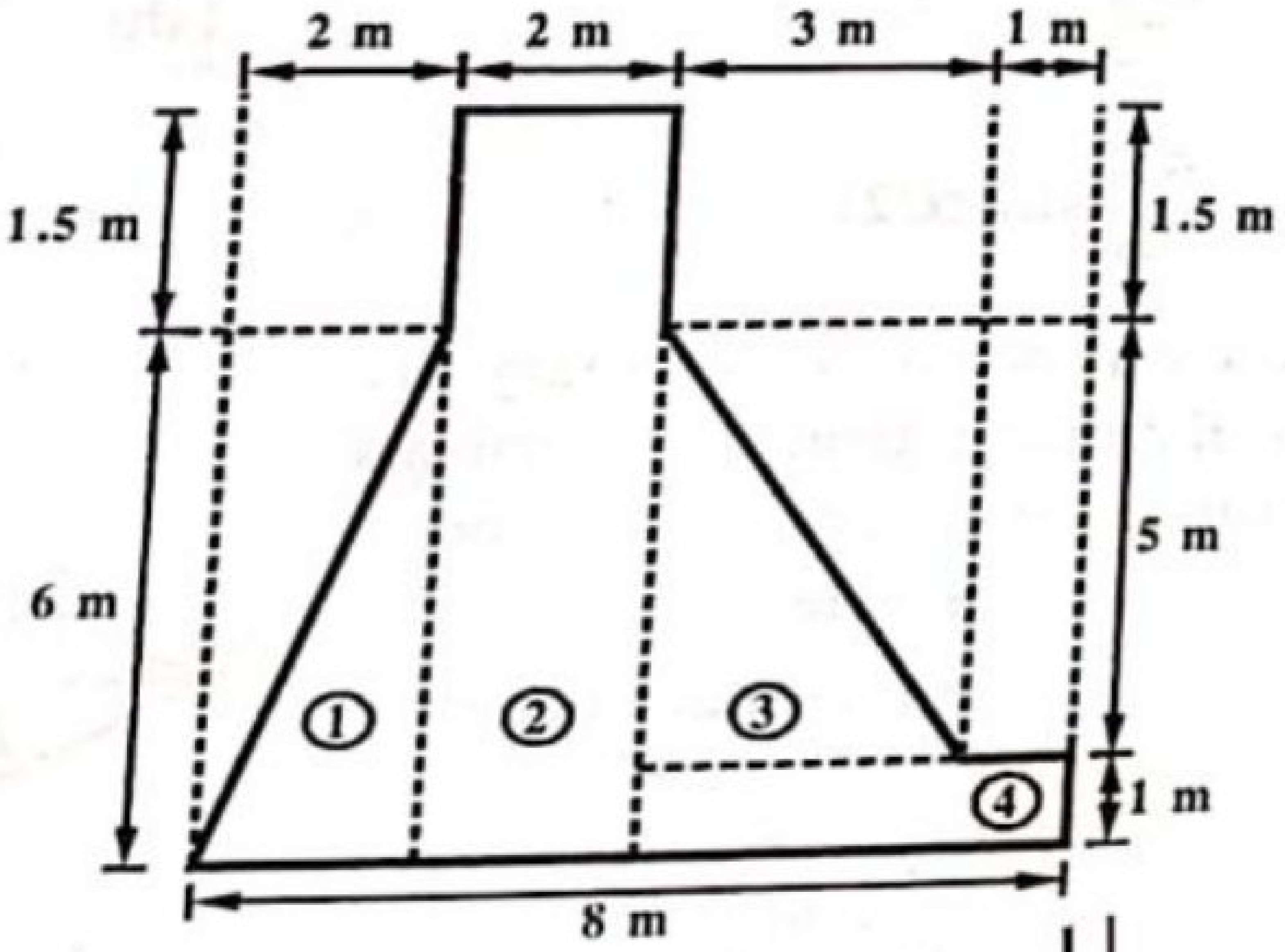


Fig. 5.8

Let left side and bottom face of the section be the axes of reference.

(i) Triangle (1)

Area, $$a_1 = \frac{1}{2} \times 2 \times 6 = 6\ m^2$$

$$x_1 = \frac{2\times2}{3} = \frac{4}{3}\ m = 1.33\ m$$

and $$y_1 = \frac{6}{3} = 2\ m$$

(ii) Rectangle (2)

Area, $$a_2 = 2 \times 7.5 = 15\ m^2$$

$$x_2 = 2 + \frac{2}{2} = 3\ m$$

and $$y_2 = \frac{7.5}{2} = 3.75\ m$$

(iii) Triangle (3)

Area, $$a_3 = \frac{1}{2} \times 3 \times 5 = 7.5\ m^2$$

$$x_3 = 4 + \frac{3}{3} = 5\ m$$

and $$y_3 = 1 + \frac{5}{3} = \frac{8}{3}\ m = 2.67\ m$$

(iv) Rectangle (4)

Area, $$a_4 = 4 \times 1 = 4\ m^2$$

$$x_4 = 4 + \frac{4}{2} = 6\ m$$

and $$y_4 = \frac{1}{2} = 0.5\ m$$

Now, distance between left side of the section and its centroid,

$$\bar{x} = \frac{a_1x_1 + a_2x_2 + a_3x_3 + a_4x_4}{a_1 + a_2 + a_3 + a_4}$$

$$= \frac{6 \times 1.33 + 15 \times 3 + 7.5 \times 5 + 4 \times 6}{6 + 15 + 7.5 + 4} = \mathbf{3.52\ m}$$ **Ans.**

and distance between bottom of the section and its centroid,

$$\bar{y} = \frac{a_1y_1 + a_2y_2 + a_3y_3 + a_4y_4}{a_1 + a_2 + a_3 + a_4}$$

$$= \frac{6\times2 + 15\times3.75 + 7.5\times2.67 + 4\times0.5}{6 + 15 + 7.5 + 4} = \mathbf{2.78\ m}$$ **Ans.**

Prob.4. Determine the centroid of the area shown in fig. 5.9 with resp to axes shown in figure.

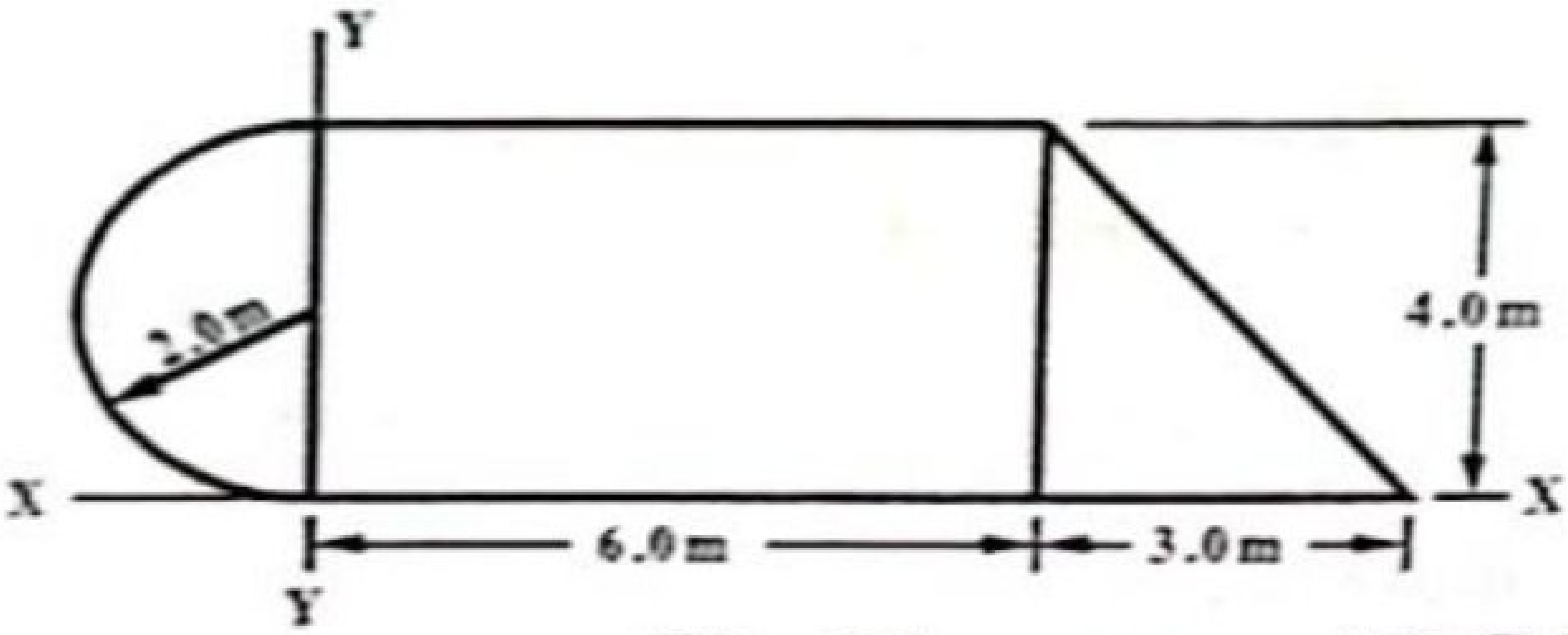


Fig. 5.9 *(R.G.P.V., June 2011)*

Sol. The given area can be divided into three sub-sections, viz. a semi-circle, a rectangle and a right angled triangle. For these sections with XX an YY as reference axes, we have

(i) Semi-circle

$$\text{Area,}\quad a_1 = \frac{\pi r^2}{2} = \frac{\pi}{2} \times (2)^2 = 6.28 \text{ m}^2$$

$$x_1 = -\frac{4r}{3\pi} = -\frac{4 \times 2}{3\pi} = -0.8488 \text{ m}$$

$$y_1 = r = 2 \text{ m}$$

(ii) Rectangle

$$\text{Area,}\quad a_2 = 4 \times 6 = 24 \text{ m}^2$$

$$x_2 = 3 \text{ m},\ \ y_2 = 2 \text{ m}$$

(iii) Right angled triangle

$$\text{Area,}\quad a_3 = \frac{1}{2} \times 3 \times 4 = 6 \text{ m}^2$$

$$x_3 = 6 + \frac{3}{3} = 7 \text{ m}$$

and
$$y_3 = \frac{4}{3} = 1.33 \text{ m}$$

Thus,
$$\bar{x} = \frac{a_1x_1 + a_2x_2 + a_3x_3}{a_1 + a_2 + a_3}$$

$$= \frac{(6.28 \times -0.8488) + (24 \times 3) + (6 \times 7)}{6.28 + 24 + 6} = 3 \text{ m} \quad \textbf{Ans.}$$

and
$$\bar{y} = \frac{a_1y_1 + a_2y_2 + a_3y_3}{a_1 + a_2 + a_3}$$

$$= \frac{(6.28 \times 2) + (24 \times 2) + (6 \times 1.33)}{6.28 + 24 + 6} = 1.89 \text{ m} \quad \textbf{Ans.}$$

MOMENT OF INERTIA OF AREA AND MASS, RADIUS OF GYRATION

Q.9. What do you understand by moment of inertia of plane areas ? Describe in brief. ***(R.G.P.V., June 2009)***

Ans. Second moment of area or moment of inertia of a plane area about a given axis is the sum of the products of the elementary areas into which the given area can be sub-divided and the squares of the distance of the centroid of these elementary areas from that axis.

Consider a plane area whose moment of inertia is required to be found out. Let this area be splitted into elementary areas $a_1, a_2, a_3,....$ If $r_1, r_2, r_3,....$ are the distances of these elementary areas from the axis about which moment of inertia has to be determined, then moment of inertia of the area will be given by,

$$I = a_1r_1^2 + a_2r_2^2 + a_3r_3^2 + ... = \Sigma\, ar^2$$

Units of moment of inertia are (units of length)^4 e.g., m^4, cm^4, km^4, etc.

Q.10. Explain the methods of determining moment of inertia of plane area.

Ans. Following two methods are used to determine moment of inertia of a plane area (or of a body) –

(i) Method of integration, and
(ii) Routh's rule.

(i) Method of Integration – Consider a plane area as shown in fig. 5.10, whose moment of inertia about XX-axis and YY-axis have to be determined. Let the whole area has been divided into a number of strips. Consider an elementary strip shown by shaded in fig. 5.10.

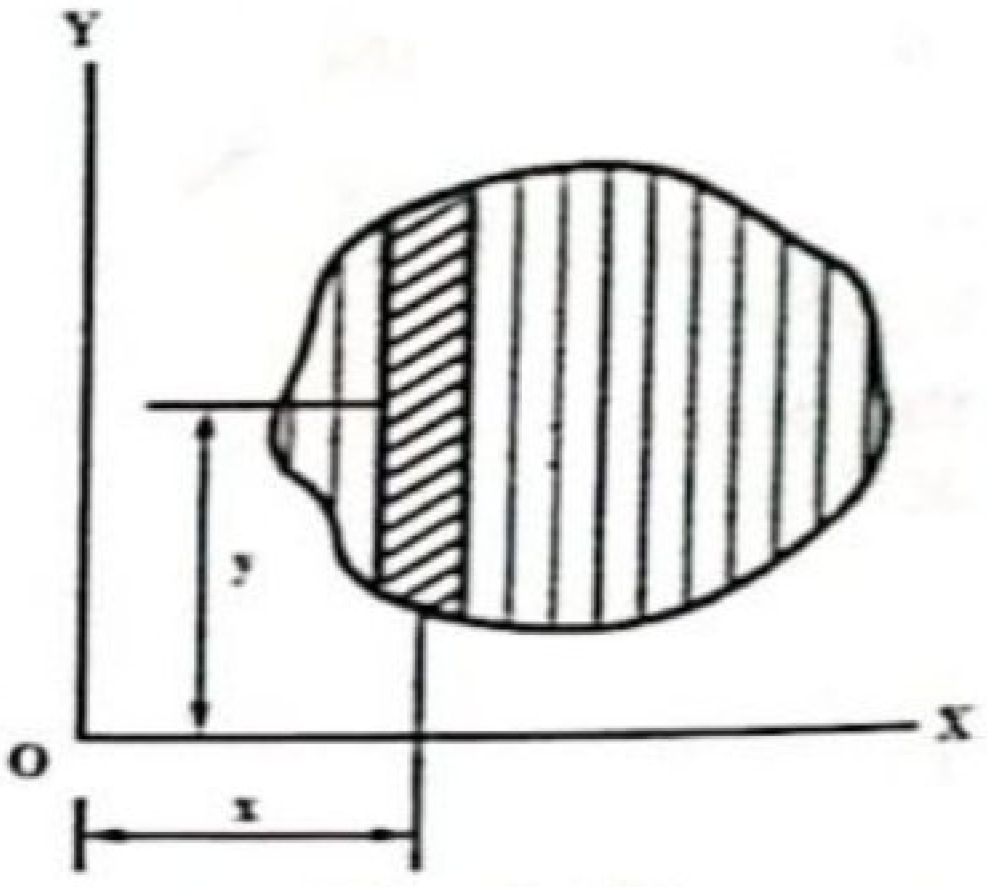


Fig. 5.10

Let dA = Area of elementary strip
x = Distance of the C.G. of the strip on XX-axis
y = Distance of the C.G. of the strip on YY-axis.

Moment of inertia of the strip about XX-axis = $dA.y^2$

Now moment of inertia of the whole area can be obtained by integrating the above equation, i.e.

$$I_{XX} = \int dA.y^2 = \Sigma dA.y^2$$

Similarly,

$$I_{YY} = \int dA.x^2 = \Sigma dA.x^2$$

(ii) Routh's Rule – Routh's rule is used to find out the moment of inertia of a body which is symmetrical about three mutually perpendicular axes. According to this rule moment of inertia of a body about any one axis passing through its centre of gravity, is given by

(a) For square and rectangular lamina

$$I = \frac{A \times S}{3}$$

(b) For circular and elliptical lamina

$$I = \frac{A \times S}{4}$$

where A = Area of the lamina

S = Sum of the squares of the two semi-axes, other than the axis about which moment of inertia is required to be found out.

Q.11. Define and explain parallel axis theorem. (R.G.P.V., Dec. 2015)
7 2 ②

Or

State and prove the theorem of parallel axis. (R.G.P.V., June 2013)

Ans. Parallel axis theorem states that, "moment of inertia of an area about an axis is equal to the sum of (i) moment of inertia about an axis passing through the centroid and parallel to the given axis, and (ii) the product of area and square of the distance between the two parallel axes."

Proof – Fig. 5.11 shows a plane lamina of area A. Let XX be the axis in the plane of lamina and passing through its C.G. AB is an axis at a distance h in the plane of given lamina and parallel to XX-axis.

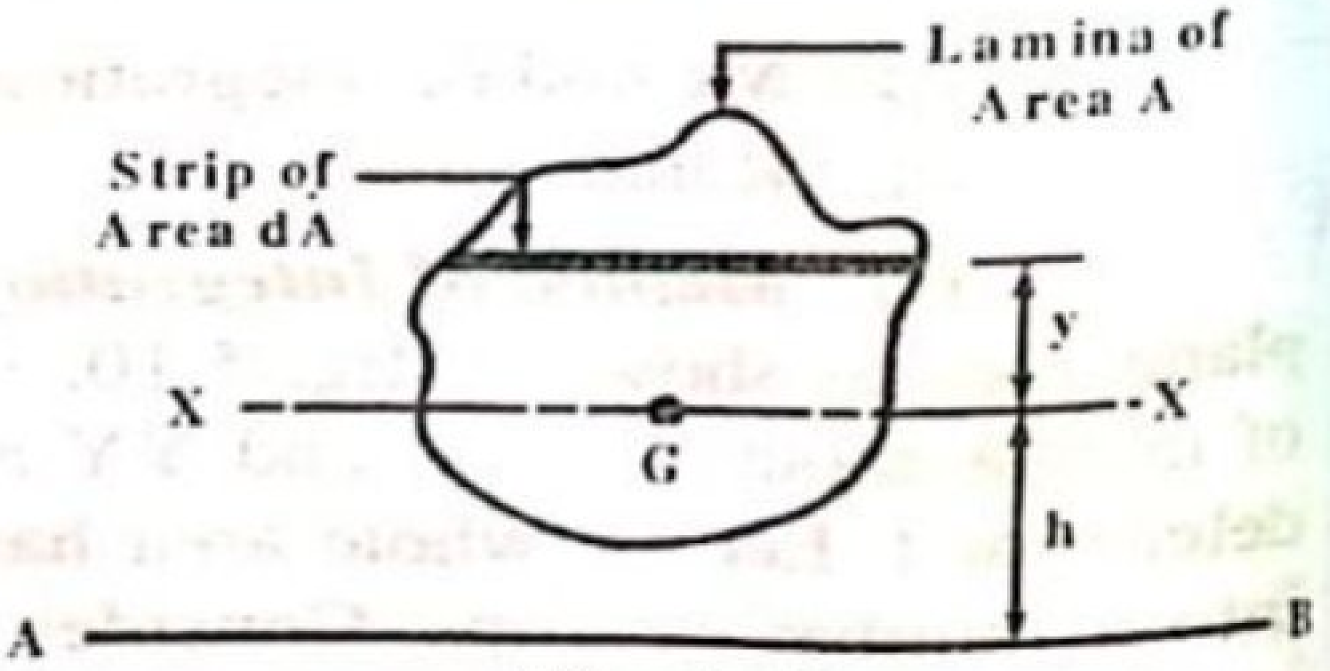


Fig. 5.11

Considering an elementary strip of lamina at a distance y from the XX-axis. Let area of the strip be dA.

Now moment of inertia of elementary strip about XX-axis

$$= dA.y^2$$

Thus, moment of inertia of total area A about XX-axis,

$$I_{XX} \text{ or } I_G = \Sigma\, dA.y^2 \quad \text{...(i)}$$

And, moment of inertia of total area about AB

$$\begin{aligned} I_{AB} &= \Sigma\, dA.\,(h + y)^2 \\ &= \Sigma\, dA\,(h^2 + y^2 + 2hy) \\ &= \Sigma\, dA.h^2 + \Sigma\, dA.y^2 + \Sigma\, 2hy dA \end{aligned}$$

As h is constant, thus,

$$I_{AB} = h^2\, \Sigma\, dA + \Sigma\, dA.y^2 + 2h\, \Sigma\, dA.y$$

But $\Sigma\, dA = A$, and also from equation (i), $\Sigma\, dA.y^2 = I_G$. Substituting these values in above equation, we get

$$I_{AB} = h^2.A + I_G + 2h\,\Sigma\, dA.y \qquad \text{...(ii)}$$

Here, $\Sigma\, dA.y$ represents the moment of the total area about XX-axis. But, moment of total area is equal to the product of total area and the distance of C.G. of total area from XX-axis. In this case distance of the C.G. of the total area from XX-axis is zero, hence $\Sigma\, dA.y$ will be equal to zero.

Substituting this value in equation (ii), we get

$$I_{AB} = h^2.A + I_G + 0$$

or $$I_{AB} = I_G + Ah^2$$ **Proved**

#2③

Q.12. State perpendicular axis theorem. *(R.G.P.V., Dec. 2014)*

Ans. Perpendicular axis theorem states that, "moment of inertia of a plane lamina about an axis perpendicular to the lamina and passing through its centroid is equal to the sum of the moment of inertias of the lamina about two mutually perpendicular axes passing through the centroid and in the plane of lamina."

Thus, if I_{XX} and I_{YY} be the moments of inertia of a plane lamina about two mutually perpendicular axes XX and YY in the plane of lamina, then the moment of inertia of the lamina about the axis ZZ perpendicular to the lamina and passing through the intersection of XX and YY-axes is given by

$$I_{ZZ} = I_{XX} + I_{YY}$$

Q.13. Enumerate the expression for perpendicular axis theorem. *(R.G.P.V., June 2016)*

Ans. Fig. 5.12 shows a lamina of area A. Let OX and OY be the two mutually perpendicular axes lying in the plane of the lamina, and OZ be an axis normal to the plane of lamina and passing through O.

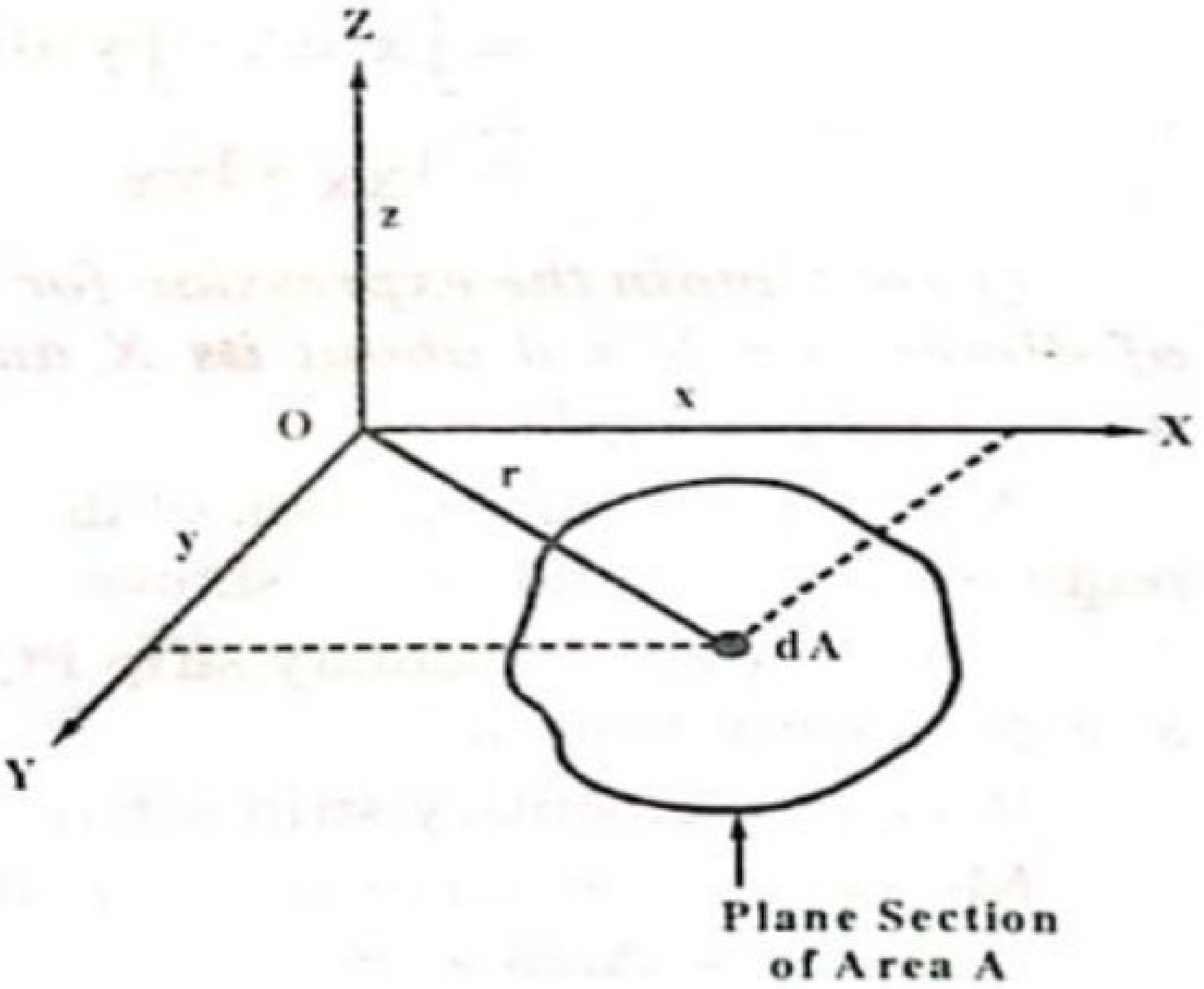


Fig. 5.12

Consider an elementary component of lamina having area dA as shown in fig. 5.12.

Let x = Distance of dA from axis OY
y = Distance of dA from axis OX
r = Distance of dA from axis OZ

From geometry of fig. 5.12, we have

$$r^2 = x^2 + y^2$$

Now moment of inertia of dA about OX-axis = $dA.y^2$

Thus, moment of inertia of total area A about OX-axis,

$$I_{XX} = \Sigma\, dA.y^2$$

Similarly, moment of inertia of total area A about OY-axis,

$$I_{YY} = \Sigma\, dA.x^2$$

and moment of inertia of total area A about OZ-axis,

$$\begin{aligned} I_{ZZ} &= \Sigma\, dA.r^2 \\ &= \Sigma\, dA\,(x^2 + y^2) \\ &= \Sigma\, dA.x^2 + \Sigma\, dA.y^2 = I_{YY} + I_{XX} \end{aligned}$$

$$\therefore \quad I_{ZZ} = I_{XX} + I_{YY}$$

Q.14. State parallel and perpendicular axis theorems. Explain any one in detail. ***(R.G.P.V., Dec. 2012)***

Ans. Refer Q.11 and Q.12.

Q.15. What do you mean by polar moment of inertia ? ***(R.G.P.V., June 2014)***

2 ⑤

Ans. Moment of inertia of a plane area about an axis perpendicular to the plane area is known as polar moment of inertia. It is denoted by I_{ZZ} or J.

Polar moment of inertia of an elemental area dA about an axis perpendicular to plane area as shown in fig. 5.13 is

$$= r^2 dA$$

Polar moment of inertia of the whole plane area,

$$I_{ZZ} = \int r^2 dA$$

From geometry of fig. 5.13,

$$r^2 = x^2 + y^2$$

$$\begin{aligned} \therefore \quad I_{ZZ} &= \int (x^2 + y^2) dA \\ &= \int x^2 dA + \int y^2 dA \\ &= I_{XX} + I_{YY} \end{aligned}$$

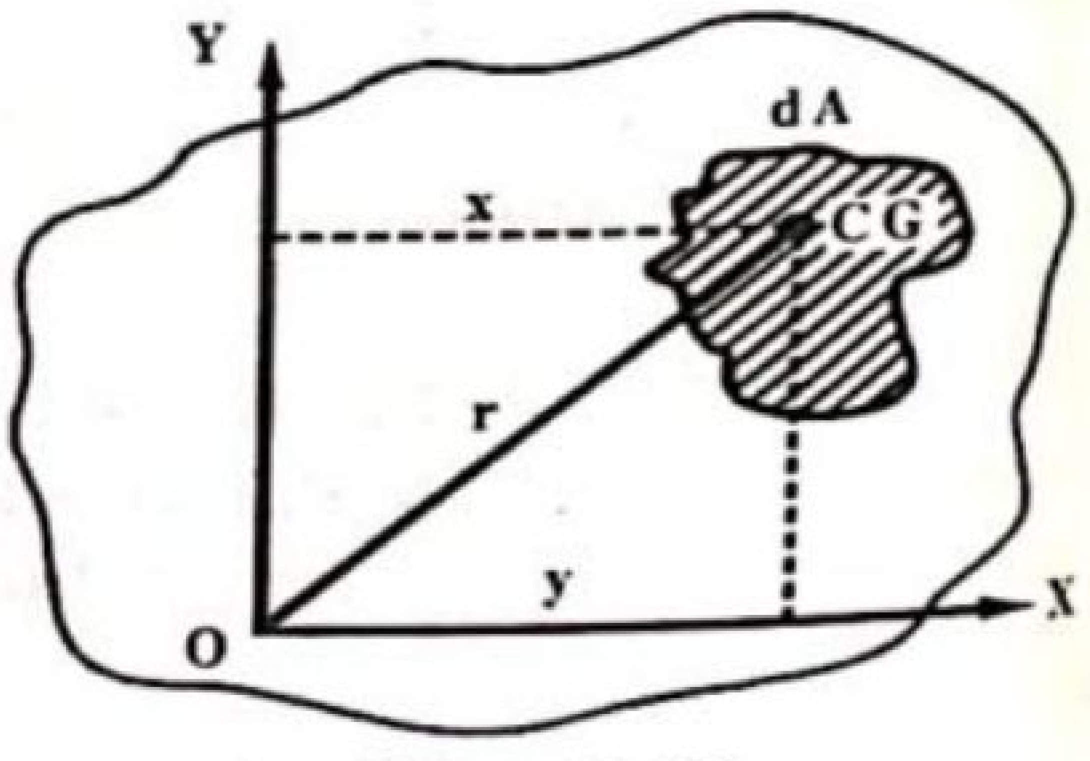


Fig. 5.13

Q.16. Obtain the expression for moment of inertia of rectangular section of dimension b × d about its X and Y axes passing through its centroid using first principle. ***(R.G.P.V., Dec. 2006)***

Ans. Rectangular section of dimensions b × d whose moment of inertia is required to be found out is shown in fig. 5.14.

Consider an elementary strip PQ of thickness dy parallel to XX-axis and at a distance y from it.

Area of elementary strip = b.dy

Moment of inertia of the strip about XX-axis

$$\begin{aligned} &= \text{Area} \times y^2 \\ &= (b.dy) \times y^2 = by^2\, dy \end{aligned}$$

Now moment of inertia of whole section can be found out by integrating the above equation between the limits $-\frac{d}{2}$ to $+\frac{d}{2}$,

$$I_{XX} = \int_{-d/2}^{d/2} by^2 dy = \left[\frac{by^3}{3}\right]_{-d/2}^{d/2}$$

$$= \frac{b}{3}\left[\left(\frac{d}{2}\right)^3 - \left(-\frac{d}{2}\right)^3\right]$$

$$= \frac{b}{3} \times \frac{d^3}{4} = \frac{bd^3}{12}$$

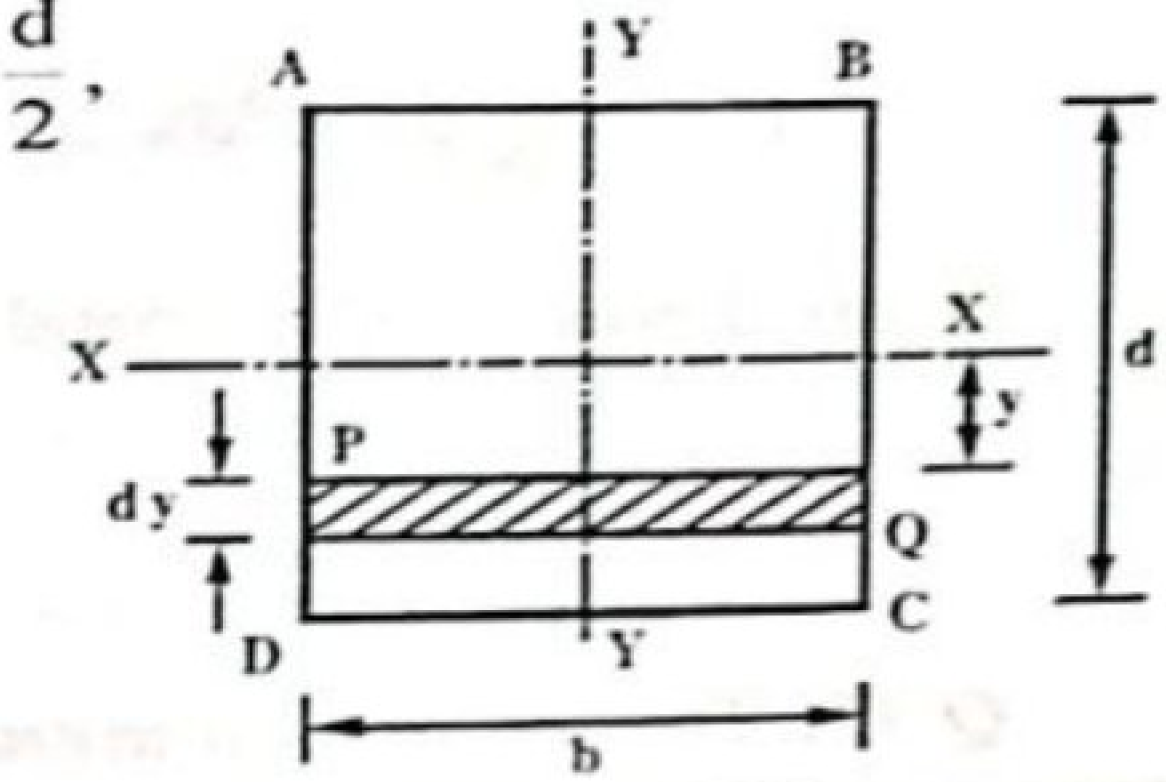


Fig. 5.14

Similarly consider another strip MN of thickness dx parallel to YY-axis and at a distance x from it as shown in fig. 5.15.

Area of the strip MN = d.dx

M.I. of strip about YY-axis = $(d.dx)x^2 = dx^2.dx$

M.I. of whole section about YY-axis,

$$I_{YY} = \int_{-b/2}^{b/2} dx^2.dx = \left[\frac{dx^3}{3}\right]_{-b/2}^{b/2}$$

$$= \frac{d}{3}\left[\left(\frac{b}{2}\right)^3 - \left(-\frac{b}{2}\right)^3\right]$$

$$= \frac{db^3}{12}$$

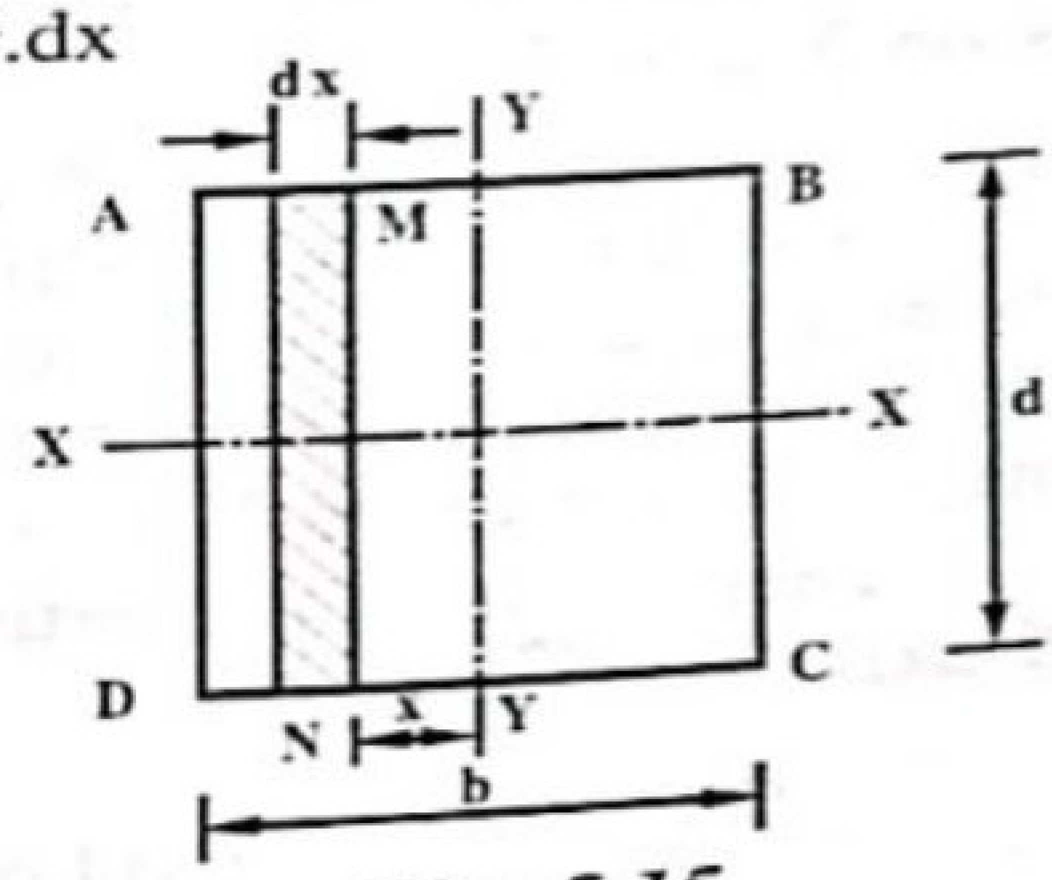


Fig. 5.15

Q.17. Deduce an expression for centroidal moment of inertia of X-X and Y-Y axes of a circular plane lamina. ***(R.G.P.V., Dec. 2015)***

Ans. Consider a circular lamina of radius, r with centre O and centroidal axes XX and YY as shown in fig. 5.16.

Consider an elementary ring of thickness dx at a radius x. Area of that elementary ring,

$$da = 2\pi x\, dx$$

M.I. of the elementary ring about XX or YY-axis

$$= \text{Area} \times (\text{Distance})^2$$
$$= (2\pi x.dx) \times (x^2)$$
$$= 2\pi x^3 dx \qquad \text{...(i)}$$

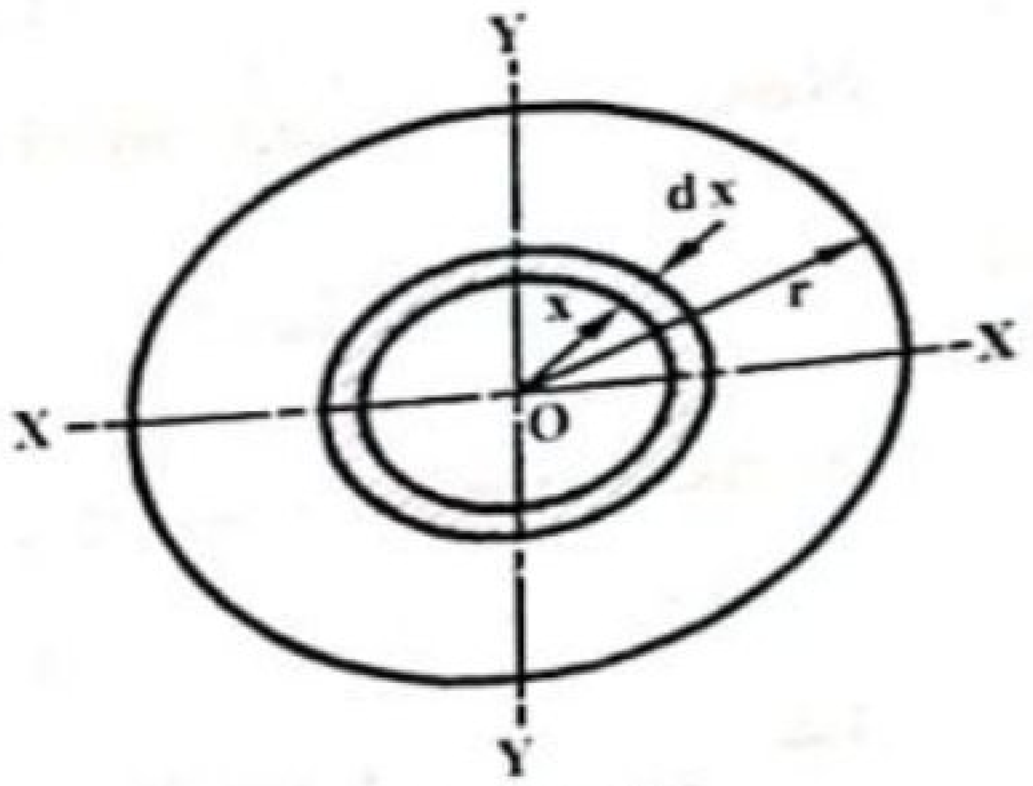


Fig. 5.16

M.I. of the whole circular lamina about the central axis can be obtained by integrating above equation between the limits 0 and r. Therefore,

$$I_{ZZ} = \int_0^r 2\pi\, x^3 dx = 2\pi\left[\frac{x^4}{4}\right]_0^r = \frac{\pi}{2} r^4 = \frac{\pi}{32} d^4 \qquad \left(\because r = \frac{d}{2}\right)$$

From theorem of perpendicular axis,

$$I_{XX} + I_{YY} = I_{ZZ}$$

$$\therefore \qquad I_{XX} = I_{YY} = \frac{I_{ZZ}}{2} = \frac{\pi}{64} d^4$$

Q.18. Determine moment of inertia of the circle about its diametral axis using first principle. ***(R.G.P.V., June 2012)***

Or

Find out the moment of inertia of a circular lamina about its diametral axis using first principle. ***(R.G.P.V., Dec. 2011)***

Ans. Consider a circle of radius r as shown in fig. 5.17, whose diameter is on X-axis. The circle can be described by the equation,

$$x^2 + y^2 = r^2 \qquad \ldots(i)$$

Now consider a thin strip PQ of thickness dx and at a distance x from the centre (or origin). Let length of strip PQ be 2y perpendicular to the X-axis.

Then, moment of inertia of the PQ about X-axis

$$= \frac{dx \times (2y)^3}{12} \qquad \left(\because \text{M.I. of rectangle} = \frac{bd^3}{12}\right)$$

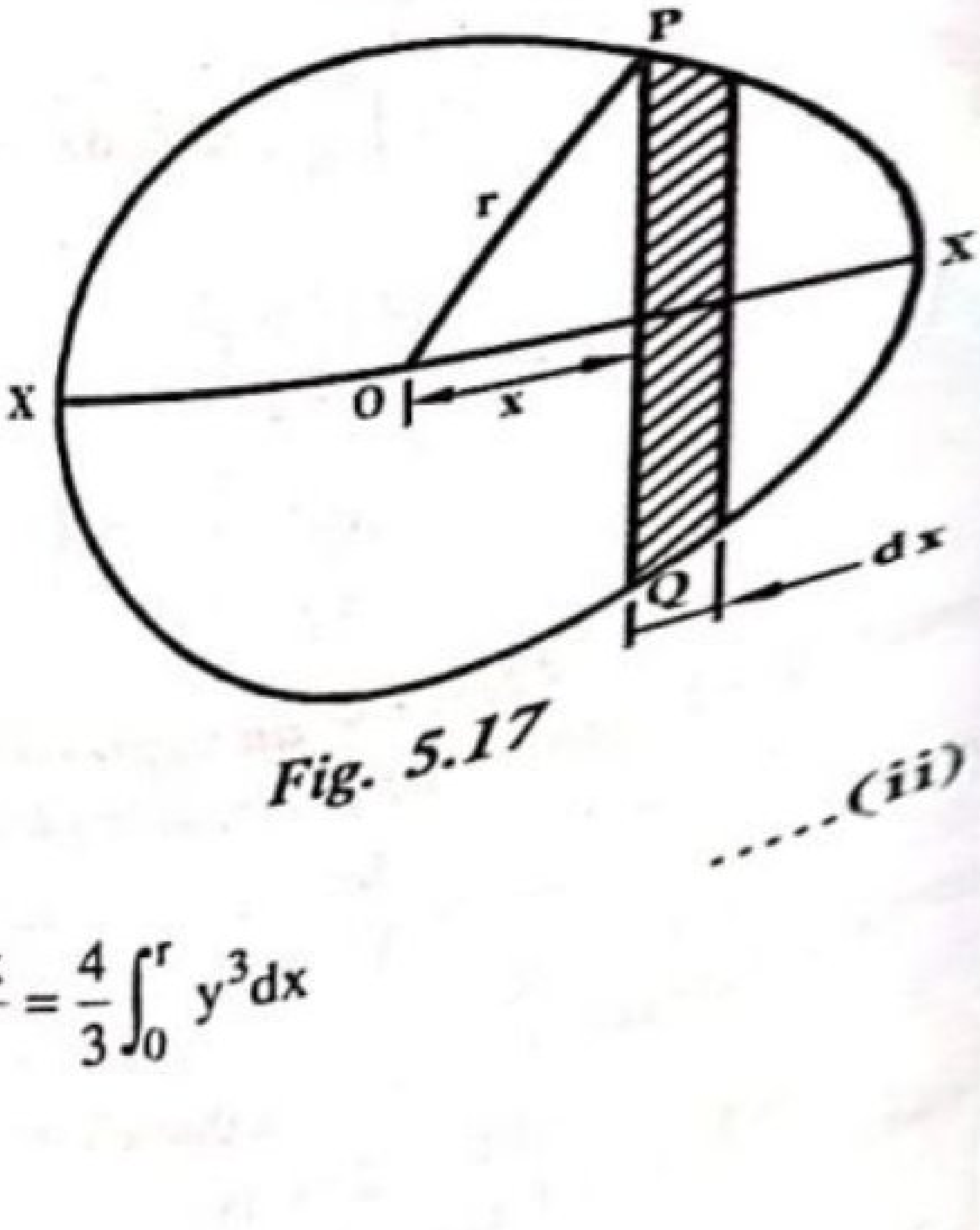


Fig. 5.17

For half part of the circle, x varies from 0 to r. Therefore, M.I. of the whole circle about X-axis (or diametral axis),

$$I_{XX} = 2\int_0^r \frac{(2y)^3 dx}{12} = \frac{4}{3}\int_0^r y^3 dx \qquad \ldots(ii)$$

Now from equation (i),

$$y^2 = r^2 - x^2$$

$$\text{or} \qquad y = (r^2 - x^2)^{1/2}$$

$$\text{or} \qquad y^3 = (r^2 - x^2)^{3/2} \qquad \ldots(iii)$$

Substituting value of y^3 in equation (ii), we get

$$I_{XX} = \frac{4}{3}\int_0^r (r^2 - x^2)^{3/2} dx$$

Let $\quad x = r \sin\theta$, then

$$dx = r\cos\theta\, d\theta$$

Substituting values of x and dx in equation (iii), we get

$$I_{XX} = \frac{4}{3}\int_0^{\pi/2}(r^2 - r^2\sin^2\theta)^{3/2}\, r.\cos\theta\, d\theta$$

$$= \frac{4}{3}r^4\int_0^{\pi/2}\cos^3\theta\cos\theta\, d\theta$$

$$= \frac{4}{3}r^4\int_0^{\pi/2}\cos^4\theta\, d\theta \quad .....(iv)$$

Integration of $\cos^4\theta$ can be obtained by using reduction formula.

$$\int\cos^n\theta\, d\theta = \frac{\sin\theta.\cos^{n-1}\theta}{n} + \frac{n-1}{n}\int\cos^{n-2}\theta\, d\theta$$

$$\therefore \quad \int\cos^4\theta\, d\theta = \frac{\sin\theta.\cos^3\theta}{4} + \frac{3}{4}\int\cos^2\theta\, d\theta$$

$$= \frac{\sin\theta.\cos^3\theta}{4} + \frac{3}{4}\left[\frac{\sin\theta.\cos\theta}{2} + \frac{1}{2}\int 1.d\theta\right]$$

$$= \frac{\sin\theta.\cos^3\theta}{4} + \frac{3}{8}\sin\theta\cos\theta + \frac{3}{8}\theta$$

Substituting this value in equation (iv), we get

$$I_{XX} = \frac{4}{3}r^4\left[\frac{\sin\theta.\cos^3\theta}{4} + \frac{3}{8}\sin\theta\cos\theta + \frac{3}{8}\theta\right]_0^{\pi/2} = \frac{4}{3}r^4.\frac{3}{8}.\frac{\pi}{2} = \frac{\pi}{4}r^4 = \frac{\pi}{64}d^4$$

Q.19. Enumerate the expression for a moment of inertia of triangular lamina about its base. ***(R.G.P.V., June 2016)***

Ans. Consider a triangular section ABC as shown in fig. 5.18.

Let b = Base of triangular section
h = Height of triangular section.

Now consider a small strip PQ of thickness dx at a distance x from vertex A. Now from similar triangles APQ and ABC,

$$\frac{PQ}{BC} = \frac{x}{h}$$

or $$PQ = \frac{BC.x}{h} = \frac{bx}{h}$$

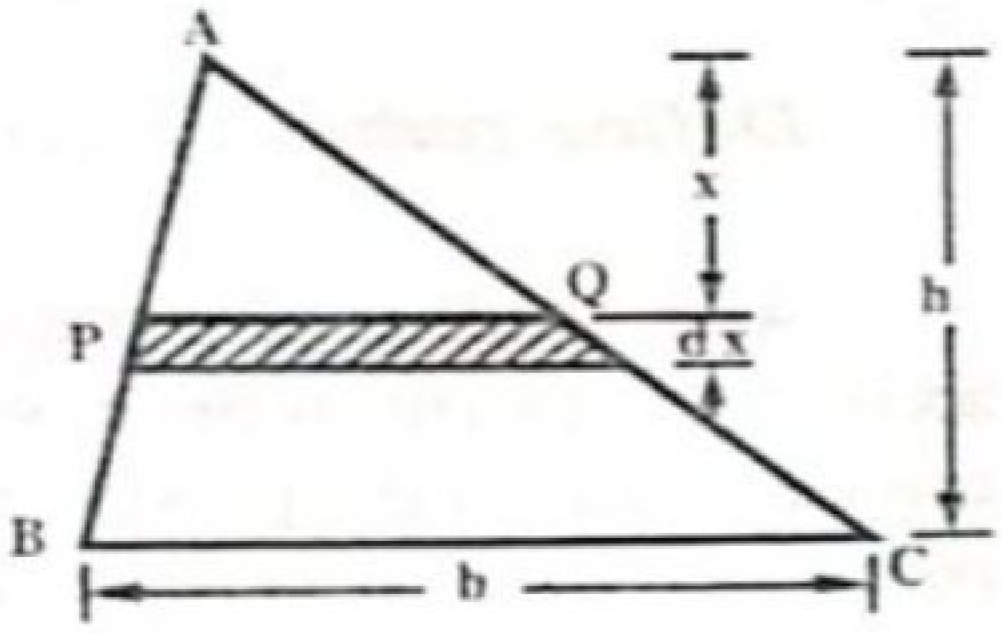


Fig. 5.18

Area of small strip $= \frac{bx}{h}.dx$

Moment of inertia of the strip about base BC

$$= \text{Area} \times (\text{Distance})^2$$

$$= \frac{bx}{h}dx(h-x)^2 = \frac{bx}{h}(h-x)^2 dx$$

Thus, moment of inertia of the whole triangular section about base B

$$I_{BC} = \int_0^h \frac{bx}{h}(h-x)^2 dx = \frac{b}{h}\int_0^h x(h-x)^2 dx$$

$$= \frac{b}{h}\int_0^h (xh^2 + x^3 - 2hx^2) dx$$

$$= \frac{b}{h}\left[\frac{x^2h^2}{2} + \frac{x^4}{4} - \frac{2hx^3}{3}\right]_0^h = \frac{b}{h}\left[\frac{h^4}{2} + \frac{h^4}{4} - \frac{2h^4}{3}\right] = \frac{bh^3}{12}$$

Q.20. Derive an expression for the moment of inertia of a triangula section about an axis passing through the C.G. of the section and parallel the base.

Ans. As derived in Q.19,

M.I. of a triangular section about its base

$$I_{BC} = \frac{bh^3}{12}$$

Distance between centre of gravity of triangular section and base BC,

$$x = \frac{h}{3}$$

Thus, M.I. of the triangular section about an axis passing through i centre of gravity and parallel to XX-axis, by using parallel axis theorem,

$$I_G = I_{BC} - ax^2$$

$$= \frac{bh^3}{12} - \left(\frac{bh}{2}\right)\left(\frac{h}{3}\right)^2 = \frac{bh^3}{12} - \frac{bh^3}{18} = \frac{bh^3}{36}$$

Q.21. Explain radius of gyration of any section. **(R.G.P.V., Dec. 2016)**

alt 2 ④

Or

Define radius of gyration and its uses. **(R.G.P.V., June 2016)**

Or

Define radius of gyration. How is it related to moment of inertia ?
[R.G.P.V., June 2008 (N)]

Ans. Radius of gyration may be defined as the distance from the reference axis to a point where whole area of given figure can considered to be concentrated and produce the same moment of inertia with respect to given reference axis. It is represented by k. Since moment of inertia has dimensions of length to fourth power, thus it can be expressed as the product of area A and square of radius of gyration, k, i.e.

$$I = Ak^2 \text{ or } k = \sqrt{\frac{I}{A}}$$

If M.I. is taken about XX-axis, then

$$k_X = \sqrt{\frac{I_{XX}}{A}}$$

and if M.I. is taken about YY-axis, then

$$k_Y = \sqrt{\frac{I_{YY}}{A}}$$

Q.22. What do you understand by second moment of area and radius of gyration ? Explain. ***(R.G.P.V., June 2014)***

Ans. Refer Q.9 and Q.21.

Q.23. Write short note on – Mass moment of inertia of solid bodies.

Ans. Solid bodies along with area also have mass. Second moment of inertia of such bodies is defined as mass moment of inertia. Mass moment of inertia is a measure of resistance that body offers to a change in its angular velocity.

Consider a body of mass M, rotating about an axis AA as shown in fig. 5.19. Let the distance of an elemental mass dM from axis be r. Then, moment of inertia of this elemental mass about axis AA will be

$$= r^2 \, dM$$

Hence total mass moment of inertia of the body about axis AA will be

$$I_{AA} = \int dMr^2$$

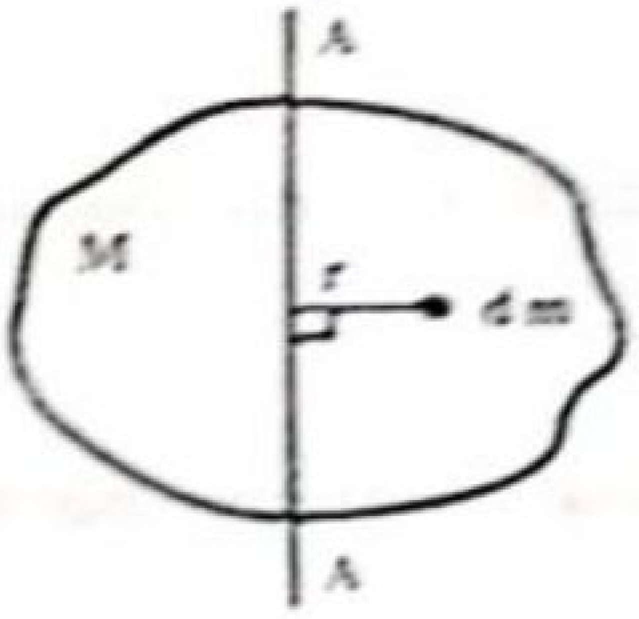


Fig. 5.19

Now if I be the mass moment of inertia of body about an axis passing through its C.G., then

$$I = Mk^2$$

where k = Radius of gyration of body.

NUMERICAL PROBLEMS

Prob.5. Find the moment of inertia of a hollow section, shown in fig. 5.20 about an axis passing through its C.G. and parallel to XX-axis.

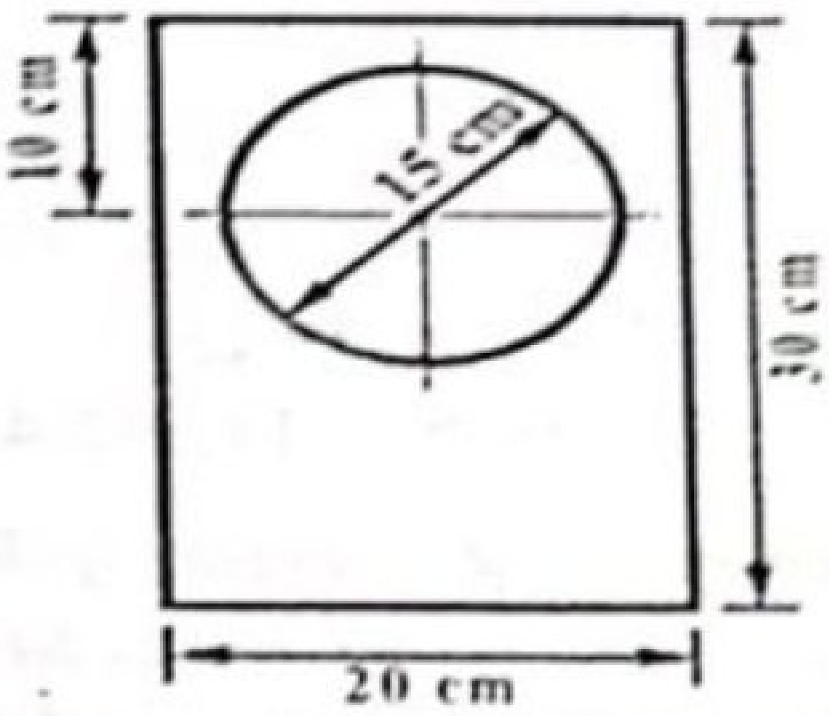


Fig. 5.20 ***(R.G.P.V., June 2015)***

Sol. As the section is symmetrical about YY-axis, therefore centroid o the section will lie on this axis. Let bottom of the section be the axis of referenc

(i) Rectangle

$$\text{Area, } a_1 = 30 \times 20 = 600 \text{ cm}^2$$

$$y_1 = \frac{30}{2} = 15 \text{ cm}$$

(ii) Circular hole

$$\text{Area, } a_2 = \frac{\pi}{4} d^2 = \frac{\pi}{4} \times (15)^2 = 176.7 \text{ cm}^2$$

$$y_2 = 30 - 10 = 20 \text{ cm}$$

∴ Distance between centroid of the section and its bottom face,

$$\bar{y} = \frac{a_1 y_1 - a_2 y_2}{a_1 - a_2}$$

$$= \frac{600 \times 15 - 176.7 \times 20}{600 - 176.7} = 12.9 \text{ cm}$$

Now moment of inertia of rectangular section about an axis passing throug its C.G. and parallel to XX-axis,

$$I_{G1} = \frac{bd^3}{12} = \frac{20 \times (30)^3}{12} = 45000 \text{ cm}^4$$

and distance between C.G. of rectangular section and XX-axis,

$$h_1 = 15 - 12.9 = 2.1 \text{ cm}$$

∴ M.I. of rectangular section about centroidal axis, parallel to XX-axis,

$$I_{XX1} = I_{G_1} + a_1 h_1^2$$

$$= 45000 + 600 \times (2.1)^2 = 47646 \text{ cm}^4$$

Similarly for circular section,

$$I_{G2} = \frac{\pi}{64} d^4 = \frac{\pi}{64} \times (15)^4 = 2485 \text{ cm}^4$$

and

$$h_2 = 20 - 12.9 = 7.1 \text{ cm}$$

∴ M.I. of circular hole about centroidal axis, parallel to XX-axis,

$$I_{XX2} = I_{G_2} + a_2 h_2^2$$

$$= 2485 + 176.7 \times (7.1)^2 = 11392.4 \text{ cm}^4$$

M.I. of the whole section about centroidal axis, parallel to XX-axis,

$$I_{XX} = I_{XX1} - I_{XX2}$$

$$= 47646 - 11392.4 = \mathbf{36253.6 \text{ cm}^4}$$ **Ans.**

Prob.6. Calculate the moment of inertia of hollow rectangular section, in which a triangular section cut from a rectangular section (fig. 5.21). Determine moment of inertia about AB axis which is base of the section.

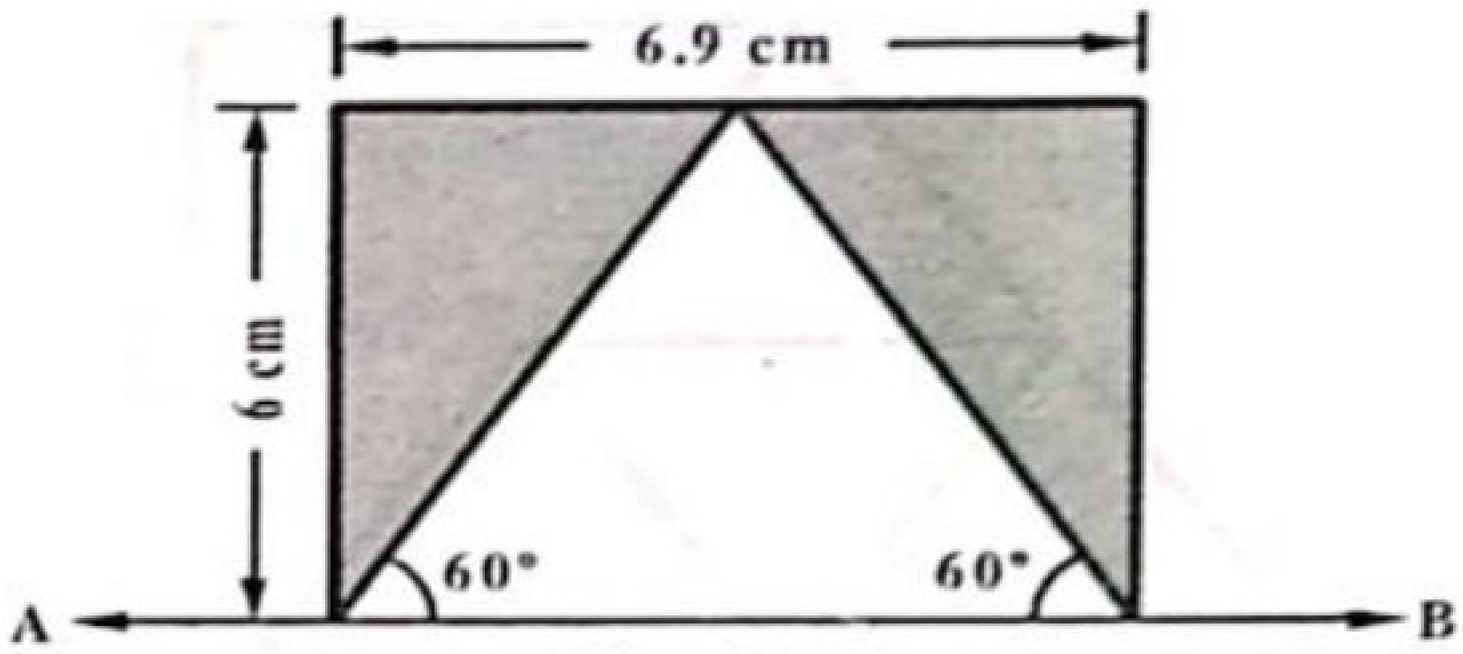


Fig. 5.21 *(R.G.P.V., Dec. 2017)*

Sol. As M.I. has to be found about AB axis, thus there is no need to determine the centroid of the section.

Now M.I. of rectangle about an axis passing through its C.G. and parallel to AB axis,

$$I_{G1} = \frac{6.9 \times 6^3}{12} = 124.2 \text{ cm}^4$$

Distance between C.G. of rectangle and AB axis

$$h_1 = 6 - 3 = 3 \text{ cm}$$

Area of rectangle, $a_1 = 6 \times 6.9 = 41.4 \text{ cm}^2$

∴ M.I. of rectangle about AB axis,

$$I_{AB1} = I_{G_1} + a_1 h_1^2$$
$$= 124.2 + 41.4 \times 3^2 = 496.8 \text{ cm}^4$$

Similarly for triangle,

$$I_{G2} = \frac{6.9 \times 6^3}{36} = 41.4 \text{ cm}^4$$

Distance between C.G. of triangle and AB axis,

$$h_2 = \frac{6}{3} = 2 \text{ cm}$$

Area of triangle,

$$a_2 = \frac{1}{2} \times 6.9 \times 6 = 20.7 \text{ cm}^2$$

∴ M.I. of triangle aboiut AB axis,

$$I_{AB2} = I_{G_2} + a_2 h_2^2$$
$$= 41.4 + 20.7 \times 2^2 = 124.2 \text{ cm}^4$$

Thus, M.I. of hollow rectangular section about AB axis,

$$I_{AB} = I_{AB1} - I_{AB2}$$
$$= 496.8 - 124.2 = \mathbf{372.6 \text{ cm}^4}$$ **Ans.**

Prob.7. Given a triangular plane lamina as shown in fig. 5.22 in which a small triangular part can be cut at the exact middle of each arm. Calculate moment of inertia about the axis AB of given plane hollow lamina as shown in figure below.

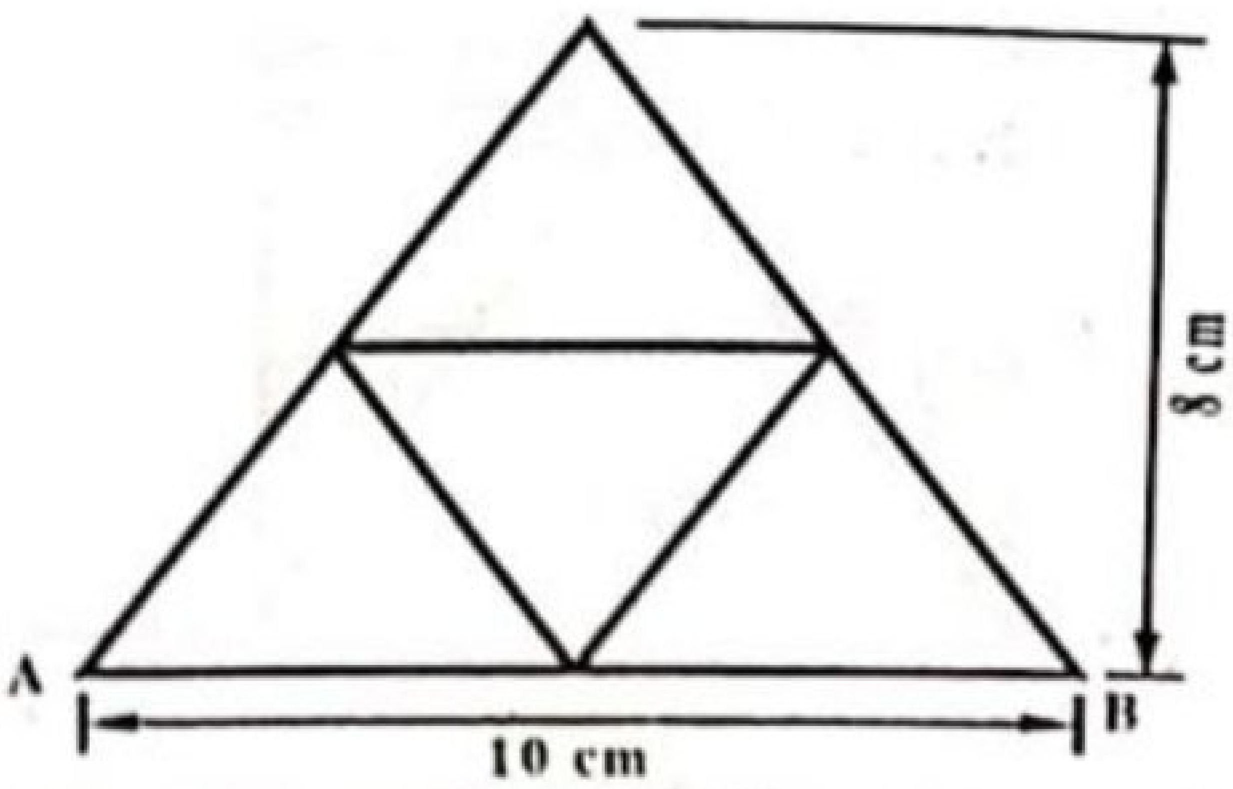


Fig. 5.22 *(R.G.P.V., Dec. 2015)*

Sol. Given, B = 10 cm, H = 8 cm.

For the small triangle by measurement,

Base, b = 5 cm and height, h = 4 cm

As M.I. of the given lamina has to be found about axis AB, thus there is no need to determine centroid of the whole section.

For large triangle,

$$\text{Area, } A = \frac{1}{2}BH = \frac{1}{2}\times 10\times 8 = 40\text{ cm}^2$$

and
$$Y = \frac{H}{3} = \frac{8}{3}\text{ cm}$$

For small triangle,

$$\text{Area, } a = \frac{1}{2}bh = \frac{1}{2}\times 5\times 4 = 10\text{ cm}^2$$

and
$$y = \frac{h}{3} = \frac{4}{3}\text{ cm}$$

M.I. of large triangle about an axis passing through its centroid and parallel to axis AB,

$$I_{G1} = \frac{BH^3}{36} = \frac{10\times(8)^3}{36} = 142.22\text{ cm}^4$$

Distance between centroid of large triangle and axis AB.

$$h_1 = Y = \frac{8}{3}\text{ cm}$$

∴ M.I. of large triangle about axis AB

$$I_{AB1} = I_{G_1} + Ah_1^2$$

$$= 142.22 + 40\times\left(\frac{8}{3}\right)^2 = 426.66\text{ cm}^4$$

Similarly for small triangle.

$$I_{G2} = \frac{bh^3}{36} = \frac{5\times(4)^3}{36} = 8.89\text{ cm}^4$$

and
$$h_2 = 4 - \frac{4}{3} = \frac{8}{3}$$

$$\therefore \quad I_{AB2} = I_{G_2} + ah_2^2$$

$$= 8.89 + 10 \times \left(\frac{8}{3}\right)^2 = 80 \text{ cm}^4$$

Thus, M.I. of the whole section about axis AB,

$$I_{AB} = I_{AB_1} - I_{AB_2}$$

$$= 426.66 - 80 = \mathbf{346.66 \text{ cm}^4}$$ **Ans.**

Prob.8. Evaluate the moment of inertia I_{XX} and I_{YY} of the shaded area as shown in fig. 5.23 about its centroidal axes.

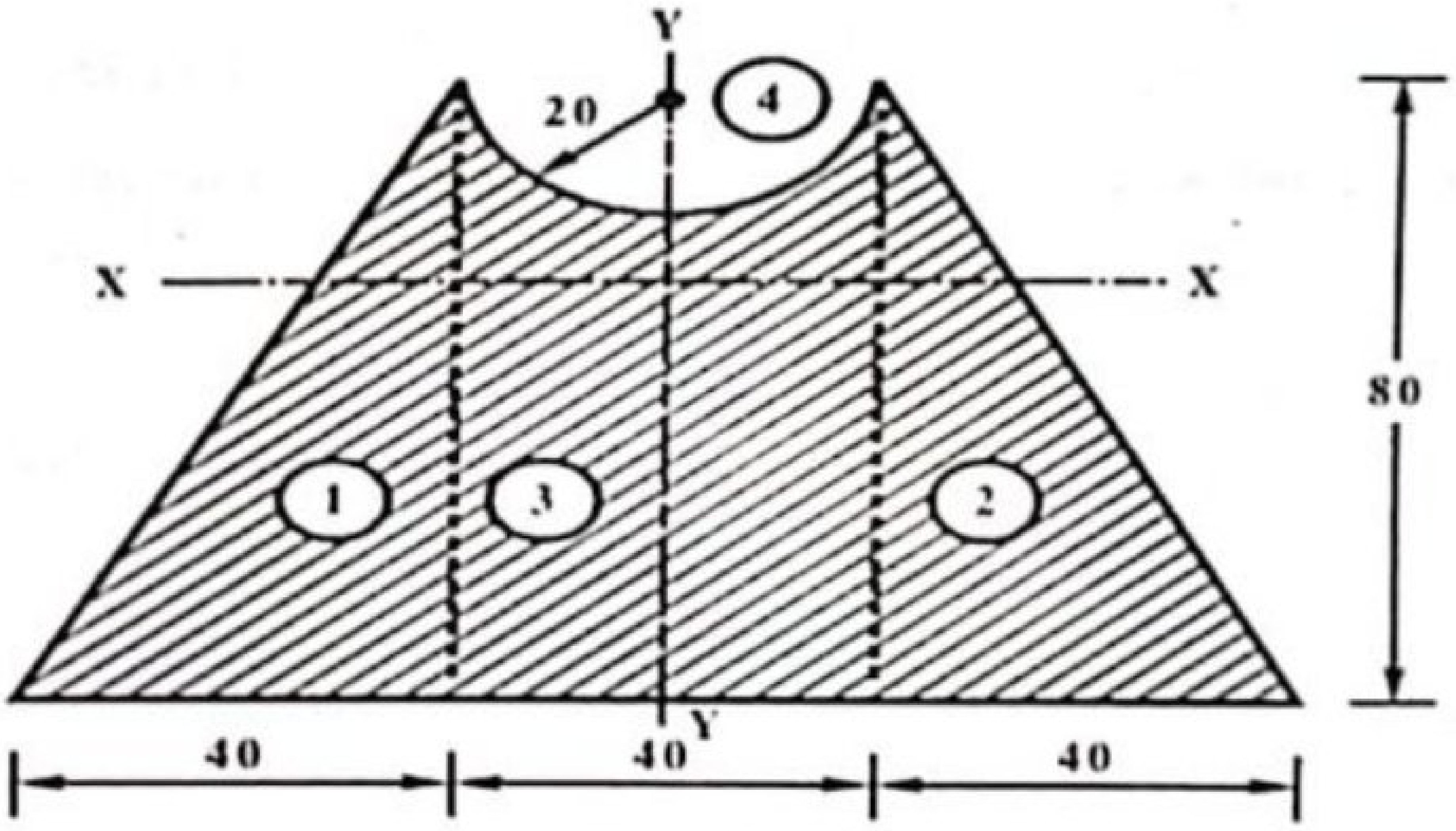


Fig. 5.23

(R.G.P.V., Dec. 2006)

Sol. The given section can be divided into four parts, viz. two triangles (1) and (2), a rectangle (3) and a semi-circle (4) as shown in fig. 5.23.

Let us first find the centroid of the section. As section is symmetrical about YY-axis, thus its centroid will lie on this axis, i.e.

$$\bar{x} = \frac{120}{2} = 60 \text{ mm}$$

For determining $\bar{y}$, let us consider bottom edge of section as reference axis.

(i) Triangle (1)

$$\text{Area, } a_1 = \frac{1}{2} \times 40 \times 80 = 1600 \text{ mm}^2$$

$$y_1 = \frac{80}{3} \text{ mm}$$

(ii) Triangle (2)

$$\text{Area, } a_2 = \frac{1}{2} \times 40 \times 80 = 1600 \text{ mm}^2$$

$$y_2 = \frac{80}{3} \text{ mm}$$

(iii) Rectangle (3)

$$\text{Area, } a_3 = 40 \times 80 = 3200 \text{ mm}^2$$

$$y_3 = \frac{80}{2} = 40 \text{ mm}$$

(iv) Semi-circle (4)

$$\text{Area, } a_4 = \frac{\pi}{2} r^2 = \frac{\pi}{2} \times (20)^2 = 628.3 \text{ mm}^2$$

$$y_4 = 80 - \frac{4r}{3\pi} = 80 - \frac{4 \times 20}{3\pi} = 71.51 \text{ mm}$$

Now distance between centroid of the section and its bottom face,

$$y = \frac{a_1 y_1 + a_2 y_2 + a_3 y_3 - a_4 y_4}{a_1 + a_2 + a_3 - a_4}$$

$$= \frac{\left(1600 \times \frac{80}{3}\right) + \left(1600 \times \frac{80}{3}\right) + (3200 \times 40) - (628.3 \times 71.51)}{1600 + 1600 + 3200 - 628.3}$$

$$= \frac{168403.6}{5771.7} = 29.2 \text{ mm}$$

Moment of Inertia about XX-axis

(i) Triangle (1)

Moment of inertia of triangle (1) about an axis passing through its centroi and parallel to XX-axis.

$$I_{G_1} = \frac{40 \times (80)^3}{36} = 568888.9 \text{ mm}^4$$

Distance between its C.G. and XX-axis.

$$h_1 = 29.2 - \frac{80}{3} = 2.53 \text{ mm}$$

M.I. of triangle (1) about XX-axis.

$$\therefore \quad I_{XX_1} = I_{G_1} + a_1 h_1^2$$

$$= 568888.9 + 1600 \times (2.53)^2 = 579130.3 \text{ mm}^4$$

(ii) Triangle (2)

Same as above

$$I_{XX_2} = 579130.3 \text{ mm}^4$$

(iii) Rectangle (3)

$$I_{G_3} = \frac{40 \times (80)^3}{12} = 1706666.7 \text{ mm}^4$$

$$h_3 = 40 - 29.2 = 10.8 \text{ mm}$$

$$\therefore \quad I_{XX_3} = I_{G_3} + a_3 h_3^2$$

$$= 1706666.7 + 3200 \times (10.8)^2$$

$$= 2079914.7 \text{ mm}^4$$

(iv) Semi-circle (4)

$$I_{G_4} = 0.11\, r^4 = 0.11 \times (20)^4 = 17600 \text{ mm}^4$$

$$h_4 = 71.51 - 29.2 = 42.31 \text{ mm}$$

$$\therefore \quad I_{XX_4} = I_{G_4} + a_4 h_4^2$$

$$= 17600 + 628.3 \times (42.31)^2$$

$$= 1142342.5 \text{ mm}^4$$

Thus, M.I. of the whole section about XX-axis,

$$I_{XX} = I_{XX_1} + I_{XX_2} + I_{XX_3} - I_{XX_4}$$

$$= 579130.3 + 579130.3 + 2079914.7 - 1142342.5$$

$$= 2095832.8$$

$$\cong \mathbf{2.096 \times 10^6 \text{ mm}^4} \qquad \textbf{Ans.}$$

Moment of Inertia about YY-axis

In this case,

$$I_{YY_1} = I_{YY_2} = \frac{80 \times (40)^3}{36} + 1600 \times \left(60 - \frac{80}{3}\right)^2$$

$$= 142222.2 + 1777777.8 = 1920000 \text{ mm}^4$$

$$I_{YY_3} = I_{G_3} = \frac{80 \times (40)^3}{12} = 426666.7 \text{ mm}^4$$

$$I_{YY_4} = I_{G_4} = \frac{\pi r^4}{8} = \frac{\pi \times (20)^4}{8} = 62831.8 \text{ mm}^4$$

Thus, M.I. of the whole section about YY-axis,

$$I_{YY} = I_{YY_1} + I_{YY_2} + I_{YY_3} - I_{YY_4}$$

$$= 1920000 + 1920000 + 426666.7 - 62831.8$$

$$= 4203834.9$$

$$\cong \mathbf{4.204 \times 10^6 \text{ mm}^4} \qquad \textbf{Ans.}$$

Prob.9. Determine moment of inertia of the Z-section about the centroidal axes XX and YY. All dimensions are in cm.

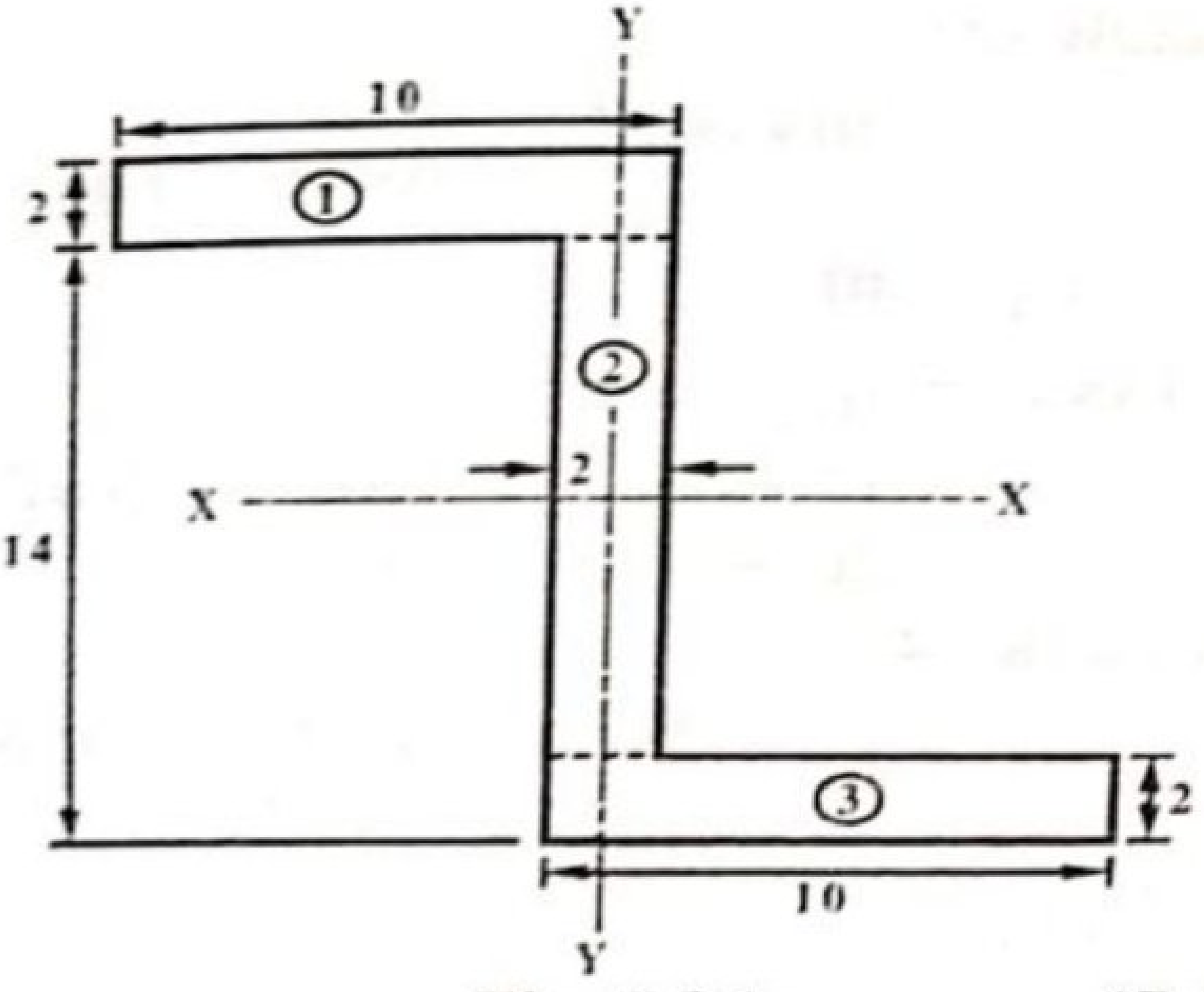


Fig. 5.24 (*R.G.P.V., Dec. 201*

Sol. The given section can be splitted into three rectangles as shown fig. 5.24. Let left edge and bottom face of the section be the axes of referenc

(i) Rectangle (1)

Area, $a_1 = 10 \times 2 = 20\text{ cm}^2$

$$x_1 = \frac{10}{2} = 5\text{ cm} \quad\text{and}\quad y_1 = 14 + \frac{2}{2} = 15\text{ cm}$$

(ii) Rectangle (2)

Area, $a_2 = 2 \times 12 = 24\text{ cm}^2$

$$x_2 = 8 + \frac{2}{2} = 9\text{ cm} \quad\text{and}\quad y_2 = 2 + \frac{12}{2} = 8\text{ cm}$$

(iii) Rectangle (3)

Area, $a_3 = 10 \times 2 = 20\text{ cm}^2$

$$x_3 = 8 + \frac{10}{2} = 13\text{ cm} \quad\text{and}\quad y_3 = \frac{2}{2} = 1\text{ cm}$$

Thus, distance between left edge of the section and its centroid,

$$\bar{x} = \frac{a_1x_1 + a_2x_2 + a_3x_3}{a_1 + a_2 + a_3} = \frac{20\times5+24\times9+20\times13}{20+24+20} = 9\text{ cm}$$

and distance between bottom face of the section and its centroid,

$$\bar{y} = \frac{a_1y_1 + a_2y_2 + a_3y_3}{a_1 + a_2 + a_3} = \frac{20\times15+24\times8+20\times1}{20+24+20} = 8\text{ cm}$$

M.I. about XX-axis

(i) Rectangle (1)

M.I. of rectangle (1) about an axis passing through its C.G. and parallel to XX-axis,

$$I_{G_1} = \frac{10\times(2)^3}{12} = \frac{20}{3}\text{ cm}^4$$

Distance between its C.G. and XX-axis, $h_1 = 15 - 8 = 7\text{ cm}$

∴ M.I. of rectangle (1) about XX-axis,

$$I_{XX_1} = I_{G_1} + a_1 h_1^2 = \frac{20}{3} + 20 \times (7)^2 = \frac{2960}{3} \text{ cm}^4$$

(ii) Rectangle (2)

$$I_{G_2} = \frac{2 \times (12)^3}{12} = 288 \text{ cm}^4$$

and $$h_2 = 8 - 8 = 0$$

∴ $$I_{XX_2} = I_{G_2} = 288 \text{ cm}^4$$

(iii) Rectangle (3)

$$I_{G_3} = I_{G_1} = \frac{20}{3} \text{ cm}^4$$

and $$h_3 = 8 - 1 = 7 \text{ cm}$$

∴ $$I_{XX_3} = I_{G_3} + a_3 h_3^2 = \frac{20}{3} + 20 \times (7)^2 = \frac{2960}{3} \text{ cm}^4$$

Thus, M.I. of the whole section about XX-axis,

$$I_{XX} = I_{XX_1} + I_{XX_2} + I_{XX_3} = \frac{2960}{3} + 288 + \frac{2960}{3} = \mathbf{2261.33 \text{ cm}^4} \quad \textbf{Ans.}$$

M.I. about YY-axis

(i) Rectangle (1)

∴ M.I. of rectangle (1) about an axis passing through its C.G. and parallel to YY-axis,

$$I_{G_1} = \frac{2 \times (10)^3}{12} = \frac{500}{3} \text{ cm}^4$$

Distance between its C.G. and YY-axis,

$$h_1 = 9 - 5 = 4 \text{ cm}$$

∴ M.I. of rectangle (1) about YY-axis,

$$I_{YY_1} = I_{G_1} + a_1 h_1^2 = \frac{500}{3} + 20 \times (4)^2 = \frac{1460}{3} \text{ cm}^4$$

(ii) Rectangle (2)

$$I_{G_2} = \frac{12 \times (2)^3}{12} = 8 \text{ cm}^4 \text{ and } h_2 = 9 - 9 = 0$$

∴ $$I_{YY_2} = I_{G_2} = 8 \text{ cm}^4$$

(iii) Rectangle (3)

$$I_{G_3} = I_{G_1} = \frac{500}{3} \text{ cm}^4$$

and $$h_3 = 13 - 9 = 4 \text{ cm}$$

∴ $$I_{YY_3} = I_{G_3} + a_3 h_3^2 = \frac{500}{3} + 20 \times (4)^2 = \frac{1460}{3} \text{ cm}^4$$

Thus, M.I. of the whole section about YY-axis,

$$I_{YY} = I_{YY_1} + I_{YY_2} + I_{YY_3} = \frac{1460}{3} + 8 + \frac{1460}{3} = \mathbf{981.33\ cm^4}$$ An

Prob.10. Find the moment of inertia of a rolled steel joist girder symmetrical I-section shown in fig. 5.25.

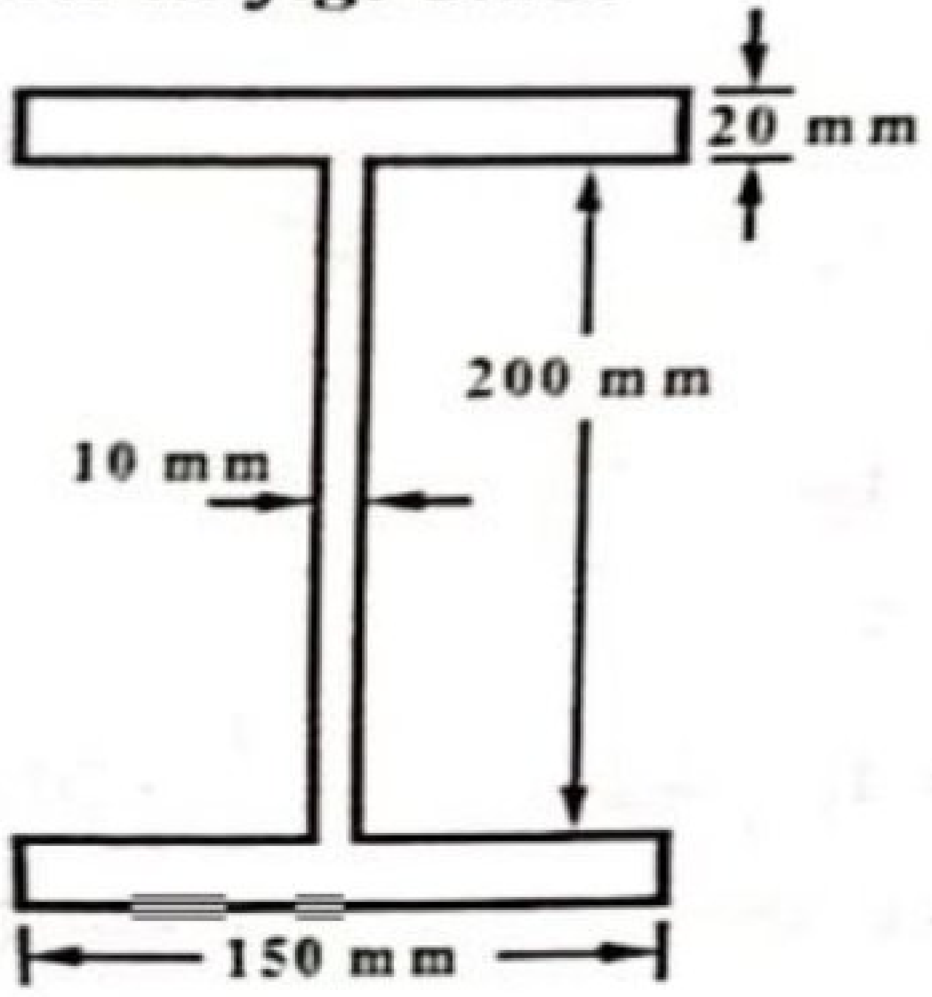


Fig. 5.25 *(R.G.P.V., Dec. 2012*

Sol. As the given section is symmetrical about both the axes, therefore it centroid will lie at its geometrical mid-point, i.e.

$$\bar{x} = 75 \text{ mm and } \bar{y} = 120 \text{ mm}$$

The given I-section can be considered as a rectangle ABCD, out of which 2 small rectangles EFGH and IJKL are scooped out as shown in fig. 5.26. Thus, M.I. of the I-section

= M.I. of rectangle ABCD – M.I. of rectangle EFGH
– M.I. of rectangle IJKL

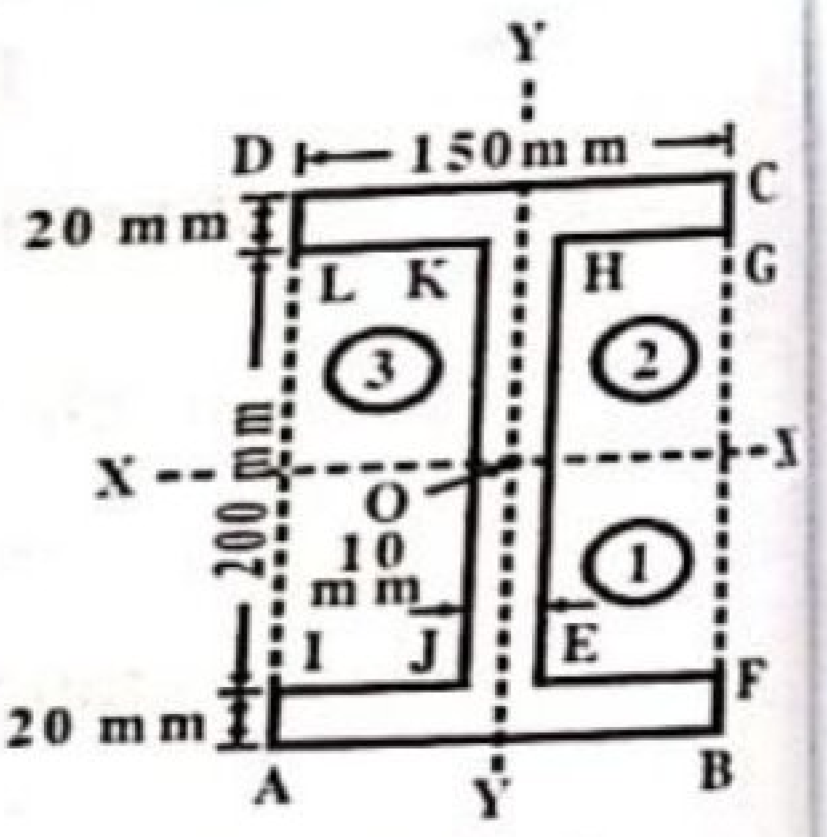


Fig. 5.26

(i) Rectangle ABCD

Area, $a_1 = 150 \times 240 = 36000 \text{ mm}^2$

$x_1 = 75 \text{ mm}, y_1 = 120 \text{ mm}$

(ii) Rectangle EFGH

Area, $a_2 = 70 \times 200 = 14000 \text{ mm}^2$

$x_2 = 80 + 35 = 115 \text{ mm}$

$y_2 = 20 + 100 = 120 \text{ mm}$

(iii) Rectangle IJKL

Area, $a_3 = a_2 = 14000 \text{ mm}^2$

$x_3 = 35 \text{ mm}, y_3 = 120 \text{ mm}$

Moment of Inertia about XX-axis

(i) Rectangle ABCD

$$I_{G_1} = \frac{150 \times (240)^3}{12} = 172.8 \times 10^6 \text{ mm}^4$$

Since rectangle is symmetrical about XX-axis, therefore

$$I_{XX_1} = I_{G_1} = 172.8 \times 10^6 \text{ mm}^4$$

(ii) Rectangle EFGH

$$I_{XX_2} = I_{G_2} = \frac{70 \times (200)^3}{12} = 46.67 \times 10^6 \text{ mm}^4$$

(iii) Rectangle IJKL

$$I_{XX_3} = I_{G_3} = \frac{70 \times (200)^3}{12} = 46.67 \times 10^6 \text{ mm}^4$$

M.I. of the whole section about XX-axis,

$$\begin{aligned} I_{XX} &= I_{XX_1} - I_{XX_2} - I_{XX_3} \\ &= 172.8 \times 10^6 - 46.67 \times 10^6 - 46.67 \times 10^6 \\ &= \mathbf{79.46 \times 10^6 \text{ mm}^4} \end{aligned}$$

Ans.

Moment of Inertia about YY-axis

(i) Rectangle ABCD

$$I_{G_1} = \frac{240 \times (150)^3}{12} = 67.5 \times 10^6 \text{ mm}^4$$

$$h_1 = x_1 - \bar{x} = 75 - 75 = 0$$

$$\therefore \quad I_{YY_1} = I_{G_1} = 67.5 \times 10^6 \text{ mm}^4$$

(ii) Rectangle EFGH

$$I_{G_2} = \frac{200 \times (70)^3}{12} = 5.72 \times 10^6 \text{ mm}^4$$

$$h_2 = 115 - 75 = 40 \text{ mm}$$

$$\begin{aligned} \therefore \quad I_{YY_2} &= I_{G_2} + a_2 h_2^2 \\ &= 5.72 \times 10^6 + 14000 \times (40)^2 \\ &= 28.12 \times 10^6 \text{ mm}^4 \end{aligned}$$

(iii) Rectangle IJKL

$$I_{G_3} = I_{G_2} = 5.72 \times 10^6 \text{ mm}^4$$

$$h_3 = 75 - 35 = 40 \text{ mm}$$

$$\therefore \quad I_{YY_3} = I_{YY_2} = 28.12 \times 10^6 \text{ mm}^4$$

M.I. of the whole section about YY-axis,

$$\begin{aligned} I_{YY} &= I_{YY_1} - I_{YY_2} - I_{YY_3} \\ &= 67.5 \times 10^6 - 28.12 \times 10^6 - 28.12 \times 10^6 \\ &= \mathbf{11.26 \times 10^6 \text{ mm}^4} \end{aligned}$$

Ans.

#③ ***Prob. 11.*** ***Determine the moment of inertia about centroidal axes XX and YY of the channel section as shown in fig. 5.27.***

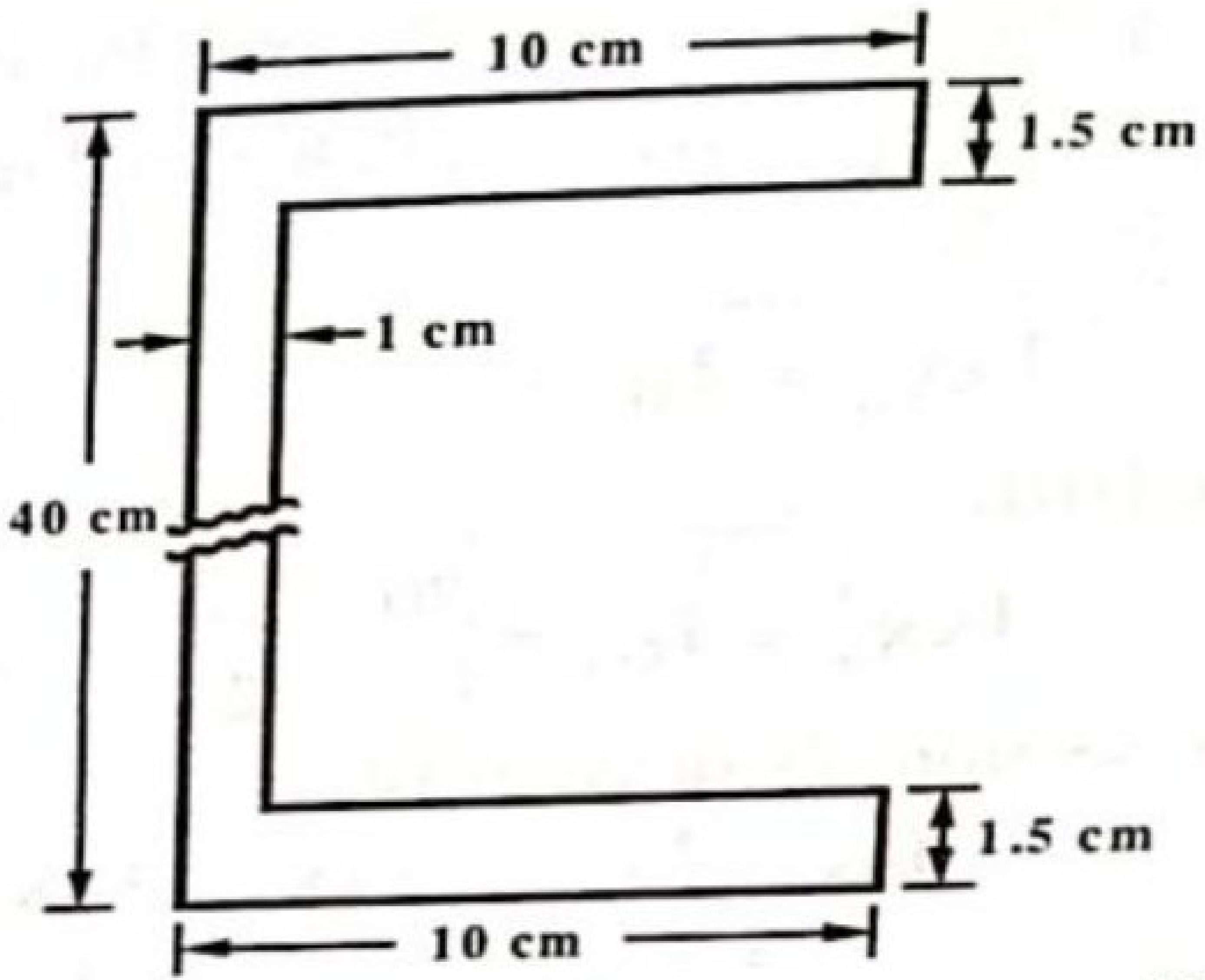


Fig. 5.27 *(R.G.P.V., Dec. 2014)*

Sol. Given section can be splitted into three rectangles as shown in fig 5.28. Let left face of the section and bottom edge be the axes of reference.

(i) Rectangle (1)

Area, $a_1 = 40 \times 1 = 40 \text{ cm}^2$

$$x_1 = \frac{1}{2} = 0.5 \text{ cm}$$

and $$y_1 = \frac{40}{2} = 20 \text{cm}$$

(ii) Rectangle (2)

Area, $a_2 = 9 \times 1.5 = 13.5 \text{ cm}^2$

$$x_2 = 1 + \frac{9}{2} = 5.5 \text{ cm}$$

and $$y_2 = 38.5 + \frac{1.5}{2} = 39.25 \text{cm}$$

(iii) Rectangle (3)

Area, $a_3 = a_2 = 13.5 \text{ cm}^2$

$x_3 = x_2 = 5.5 \text{ cm}$

and $$y_3 = \frac{1.5}{2} = 0.75 \text{ cm}$$

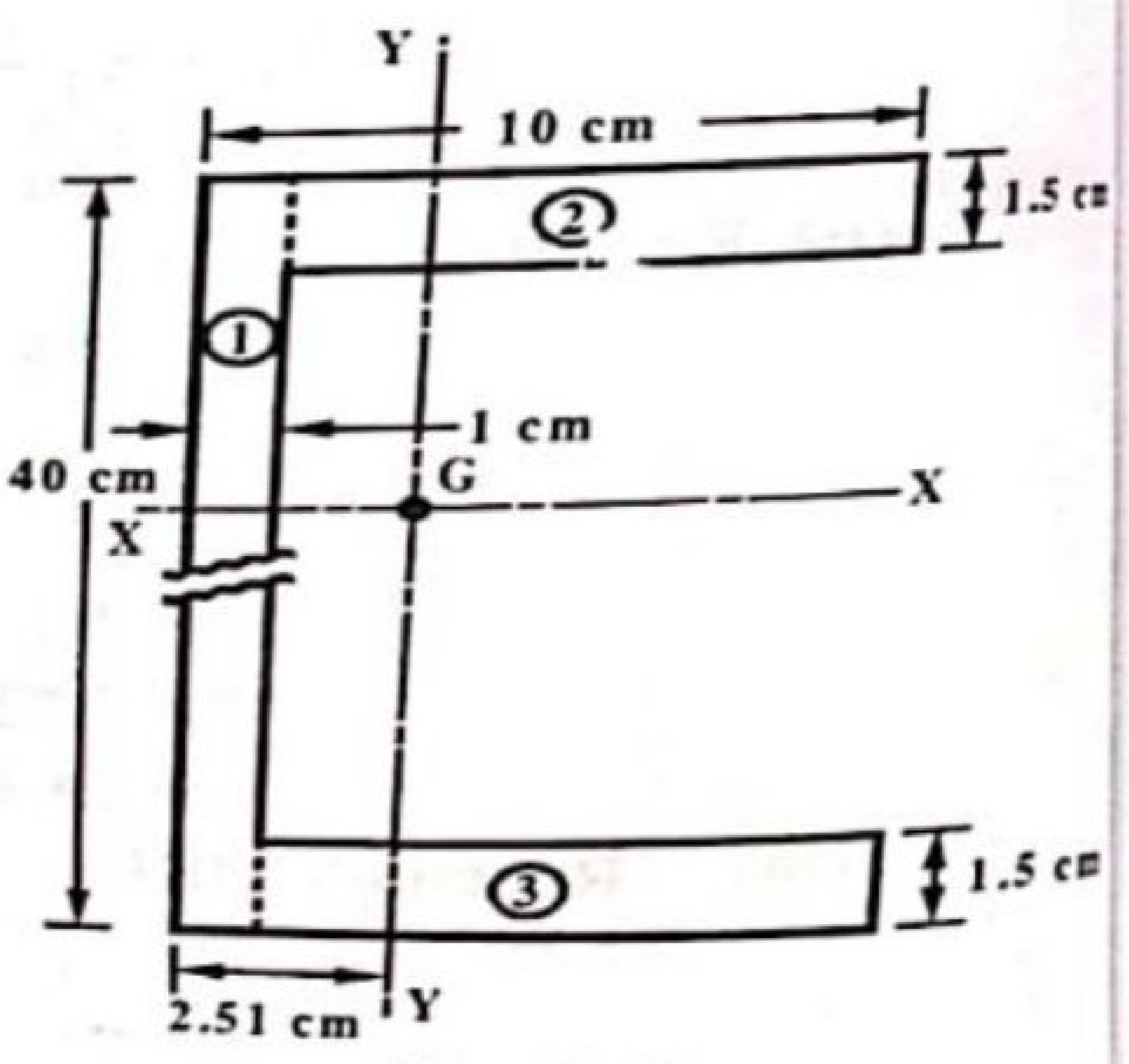


Fig. 5.28

Distance of centroid of the section from its left face,

$$\bar{x} = \frac{a_1 x_1 + a_2 x_2 + a_3 x_3}{a_1 + a_2 + a_3}$$

$$= \frac{(40 \times 0.5) + (13.5 \times 5.5) + (13.5 \times 5.5)}{40 + 13.5 + 13.5} = 2.51 \text{cm}$$

Since section is symmetrical about XX-axis, therefore

$$y = \frac{40}{2} = 20\,\text{cm}$$

Moment of Inertia about XX-axis

M.I. of rectangle (1) about XX-axis

$$I_{XX_1} = I_{G_1} = \frac{1\times(40)^3}{12} = 5333.33\,\text{cm}^4$$

M.I. of rectangle (2) about an axis passing through its C.G. and parallel to XX-axis,

$$I_{G_2} = \frac{9\times(1.5)^3}{12} = 2.531\,\text{cm}^4$$

Distance between centroid of rectangle (2) and XX-axis

$$h_2 = 39.25 - 20 = 19.25\,\text{cm}$$

∴ M.I. of rectangle (2) about XX-axis,

$$I_{XX_2} = I_{G_2} + a_2 h_2^2$$
$$= 2.531 + 13.5 \times (19.25)^2 = 5005.1\,\text{cm}^4$$

Since rectangles (2) and (3) are identical, therefore

$$I_{XX_3} = I_{XX_2} = 5005.1\,\text{cm}^4$$

M.I. of the whole channel section about XX-axis,

$$I_{XX} = I_{XX_1} + I_{XX_2} + I_{XX_3}$$
$$= 5333.33 + 5005.1 + 5005.1 = \mathbf{15343.53\,cm^4}$$ **Ans.**

Moment of Inertia about YY-axis

M.I. of rectangle (1) about an axis passing through its C.G. and parallel to YY-axis,

$$I_{G_1} = \frac{40\times(1)^3}{12} = 3.33\,\text{cm}^4$$

Distance between centroid of rectangle (1) and YY-axis,

$$h_1 = 2.51 - 0.5 = 2.01\,\text{cm}$$

∴ M.I. of rectangle (1) about YY-axis,

$$I_{YY_1} = I_{G_1} + a_1 h_1^2$$
$$= 3.33 + 40 \times (2.01)^2 = 164.934\,\text{cm}^4$$

M.I. of rectangle (2) about an axis passing through its C.G. and parallel to YY-axis,

$$I_{G_2} = \frac{1.5\times(9)^3}{12} = 91.125\,\text{cm}^4$$

Distance between centroid of rectangle (2) and YY-axis,

$$h_2 = 5.5 - 2.51 = 2.99\,\text{cm}$$

∴ M.I. of rectangle (2) about YY-axis,

$$I_{YY_2} = I_{G_2} + a_2h_2^2$$
$$= 91.125 + 13.5 \times (2.99)^2 = 211.816 \text{ cm}^4$$

Since rectangles (2) and (3) are identical, therefore

$$I_{YY_3} = I_{YY_2} = 211.816 \text{ cm}^4$$

M.I. of the whole channel section about YY-axis,

$$I_{YY} = I_{YY_1} + I_{YY_2} + I_{YY_3}$$
$$= 164.934 + 211.816 + 211.816 = \mathbf{588.566 \text{ cm}^4} \quad \text{An}$$

Prob.12. For a circular pipe of 150 mm external diameter and 120 m internal diameter, determine –

(i) Moment of inertia about its diameter

(ii) The radius of gyration (iii) The polar moment of inertia.

(R.G.P.V., Dec. 201

Sol. Given, $D_1 = 150$ mm or $R_1 = 75$ mm, $D_2 = 120$ mm or $R_2 = 60$ m

(i) Moment of inertia about its diameter

The cross-section of the pipe is shown in fig. 5.29.

The moment of inertia of the pipe about its diameter (X-X) will b given as,

$$I = \frac{\pi}{4}(R_1^4 - R_2^4) = \frac{\pi}{4}[(75)^4 - (60)^4]$$
$$= \mathbf{14671728.57 \text{ mm}^4} \quad \textbf{Ans.}$$

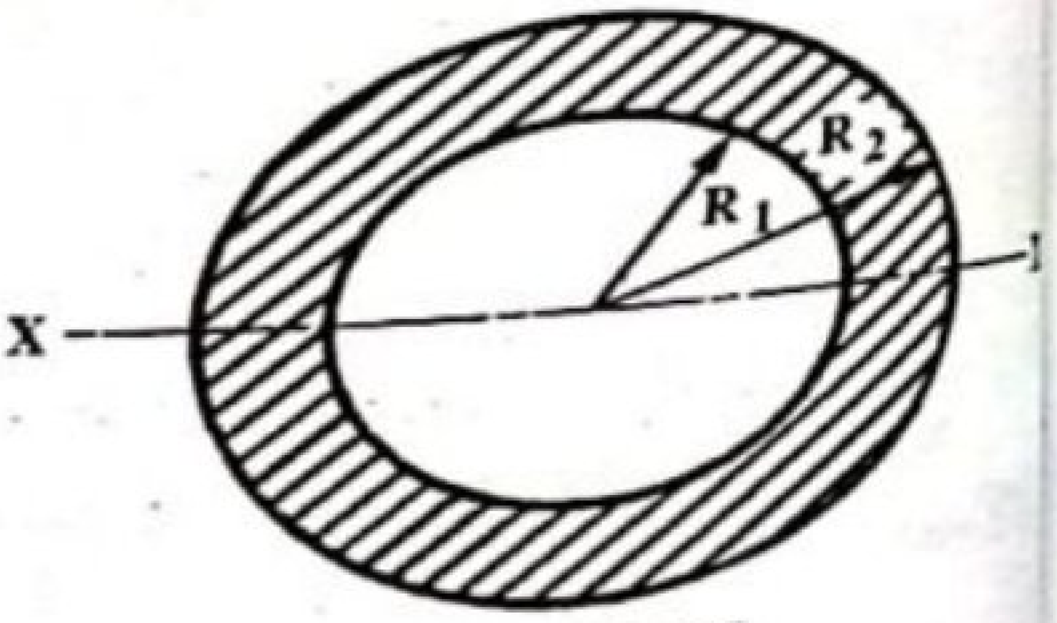


Fig. 5.29

(ii) Radius of gyration

As we know moment of inertia of a cross-section is given as,

$$I = Ak^2$$
$$\frac{\pi}{4}(R_1^4 - R_2^4) = \pi(R_1^2 - R_2^2).k^2$$

or
$$k^2 = \frac{R_1^2 + R_2^2}{4}$$

or
$$k = \sqrt{\frac{R_1^2 + R_2^2}{4}} = \sqrt{\frac{(75)^2 + (60)^2}{4}} = \mathbf{48 \text{ mm}} \quad \text{Ans}$$

(iii) Polar moment of inertia

Polar moment of inertia of the section shown in fig. 5.29 will be

$$J = \frac{\pi}{32}(D_1^4 - D_2^4) = \frac{\pi}{2}(R_1^4 - R_2^4)$$
$$= \frac{\pi}{2}\left[(75)^4 - (60)^4\right] = \mathbf{29343457.13 \text{ mm}^4} \quad \text{Ans.}$$

INTRODUCTION TO PRODUCT OF INERTIA AND PRINCIPLE AXES

# 2(6)

Q.24. What is product of inertia ? *(R.G.P.V., Dec. 2015)*

Ans. If an elemental area is multiplied by the product of its co-ordinates and integrated for entire area, is known as the ***product of inertia*** or ***product of area*** about X and Y axes.

If dA is an elemental area of the plane area A and its co-ordinates are (x, y) with respect to rectangular axes OX and OY, then product of inertia of this area about X and Y axes will be given as,

$$I_{XY} = \int xy \, dA$$

The product of inertia thus may be defined as the sum of a number of terms each consisting of an area multiplied by the distance of that area with respect to X and Y axes. Since there is a product of distances x and y. The product of inertia may be positive or negative, depending upon the location of area relative to the axes. If area lies principally in the first or third quadrants, it is positive, and if area lies principally in the second or fourth quadrants, it is negative.

If given area is symmetrical about either or both axes of reference, then product of inertia of given area with respect to those axes is zero.

Consider an area symmetrical about YY-axis as shown in fig. 5.30.

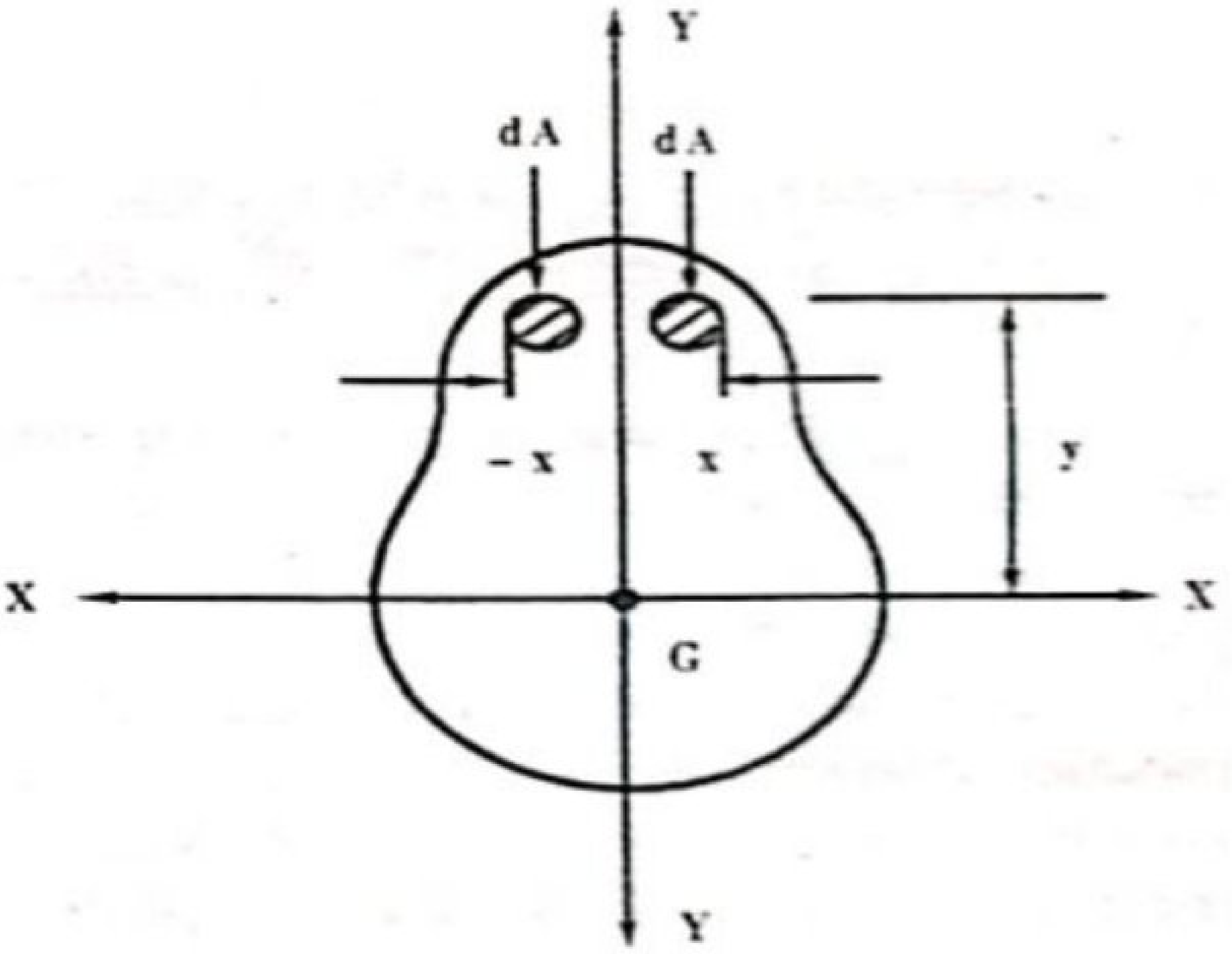


Fig. 5.30

For every area dA at a distance x from YY-axis, there exists another area dA at a distance –x from YY. Hence, the contribution of product of area of each element is xy.dA with opposite signs and hence, the net result is zero. Since the entire area A is composed of such pairs of elemental area dA, the product of inertia will be equal to zero.

Q.25. Determine product of inertia of a rectangular section with respect to a pair of axes through adjacent sides.

Ans. A rectangular section ABCD is shown in fig. 5.31. Let OX and OY be the axes about which the product of inertia has to be found out.

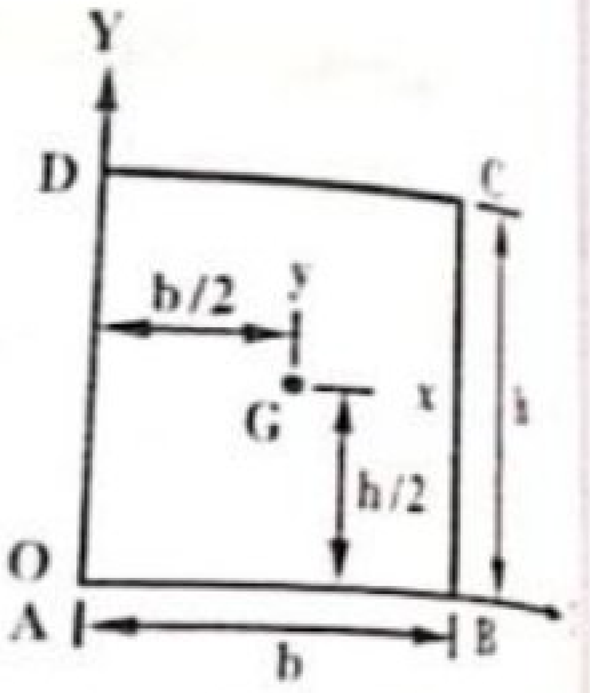


Fig. 5.31

Let b = Width of rectangle
h = Height of rectangle.

Product of inertia of rectangle ABCD with respect to OX and OY axes will be given as

$$I_{XY} = I_{xy} + a\bar{x}\,\bar{y} \qquad \text{...(i)}$$

where I_{xy} = Product of inertia of rectangle ABCD about x and y axes passing through the centroid of rectangle
a = Area of rectangle = b.h
x = Distance of centroid from OY-axis
y = Distance of centroid from OX-axis.

As rectangle is symmetrical about its centroidal axes, thus

$$I_{xy} = 0$$

Hence, from equation (i)

$$I_{XY} = 0 + bh.\frac{b}{2}.\frac{h}{2} = \frac{b^2h^2}{4}$$

Q.26. Explain the following terms –
(i) Principal axes (ii) Radius of gyration.

(R.G.P.V., June 201

Ans. (i) Principal Axes – From any point in a given area an axis can b drawn through which moment of inertia is either greater or less than for an other axes passing through the given point. In fact there are always tw perpendicular axes through which M.I. of area is greater or less respectively These axes are called principal axes of inertia for an area. Axes for which th product of inertia is zero are called ***principal axes.*** As product of inertia of a area become zero for the axes of symmetry, therefore, axes of symmetry ar the principal axes. There are two principal axes, namely – Major principa axis, and minor principal axis.

(ii) Radius of Gyration – Refer Q.21.

Q.27. Define and give expressions for principal moments of inertia.

Ans. Moment of inertia about a principal axis is called as the ***principal moment of inertia.*** For two principal axes (major and minor) there are two values of principal moments of inertia, which are

Major (or maximum) principal moment of inertia,

$$I_{max} = \frac{I_{XX} + I_{YY}}{2} + \sqrt{\left(\frac{I_{XX} - I_{YY}}{2}\right)^2 + (I_{XY})^2}$$

and minor (or minimum) principal moment of inertia,

$$I_{min} = \frac{I_{XX} + I_{YY}}{2} - \sqrt{\left(\frac{I_{XX} - I_{YY}}{2}\right)^2 + (I_{XY})^2}$$

where I_{XX} = M.I. of given area about co-ordinate axis XX passing through the centroid = $\int y^2 \, dA$

I_{YY} = M.I. of given area about co-ordinate axis YY passing through the centroid = $\int x^2 \, dA$

I_{XY} = Product of Inertia = $\int xy \, dA$.

Q.28. Explain principle axes and principle moment of inertia.

(R.G.P.V., Dec. 2017)

Ans. Refer Q.26 and Q.27.

NUMERICAL PROBLEMS

Prob.13. Determine the principal moment of inertia of the section shown in fig. 5.32 about its centroid. All dimensions are in mm.

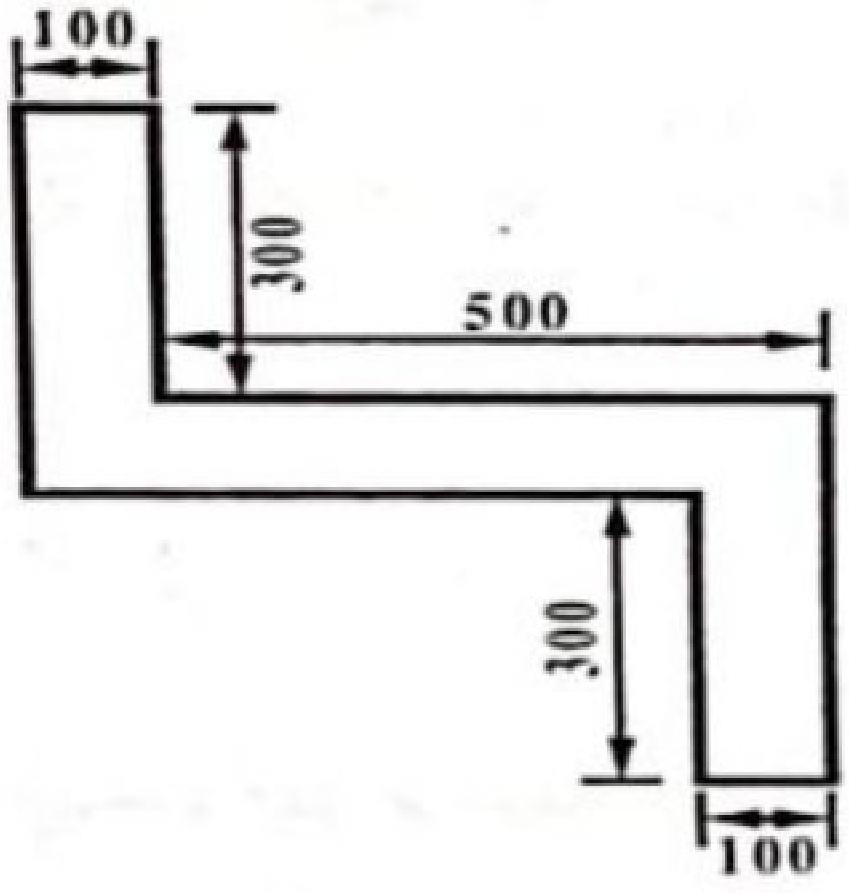


Fig. 5.32 ***(R.G.P.V., June 2013)***

Sol. The given section is symmetrical about both XX and YY axes, therefore its C.G. will lie at its geometrical centre as shown in fig. 5.33. Now to determine the M.I. divide the section into three rectangles as shown in fig. 5.33.

(i) Rectangle (1)

$$I_{XX_1} = I_{G_1} + a_1 h_1^2$$

$$= \frac{100 \times (300)^3}{12} + (100 \times 300) \times (200)^2 = 1425 \times 10^6 \text{ mm}^4$$

$$I_{YY_1} = \frac{300 \times (100)^3}{12} + (100 \times 300) \times (250)^2 = 1900 \times 10^6 \text{ mm}^4$$

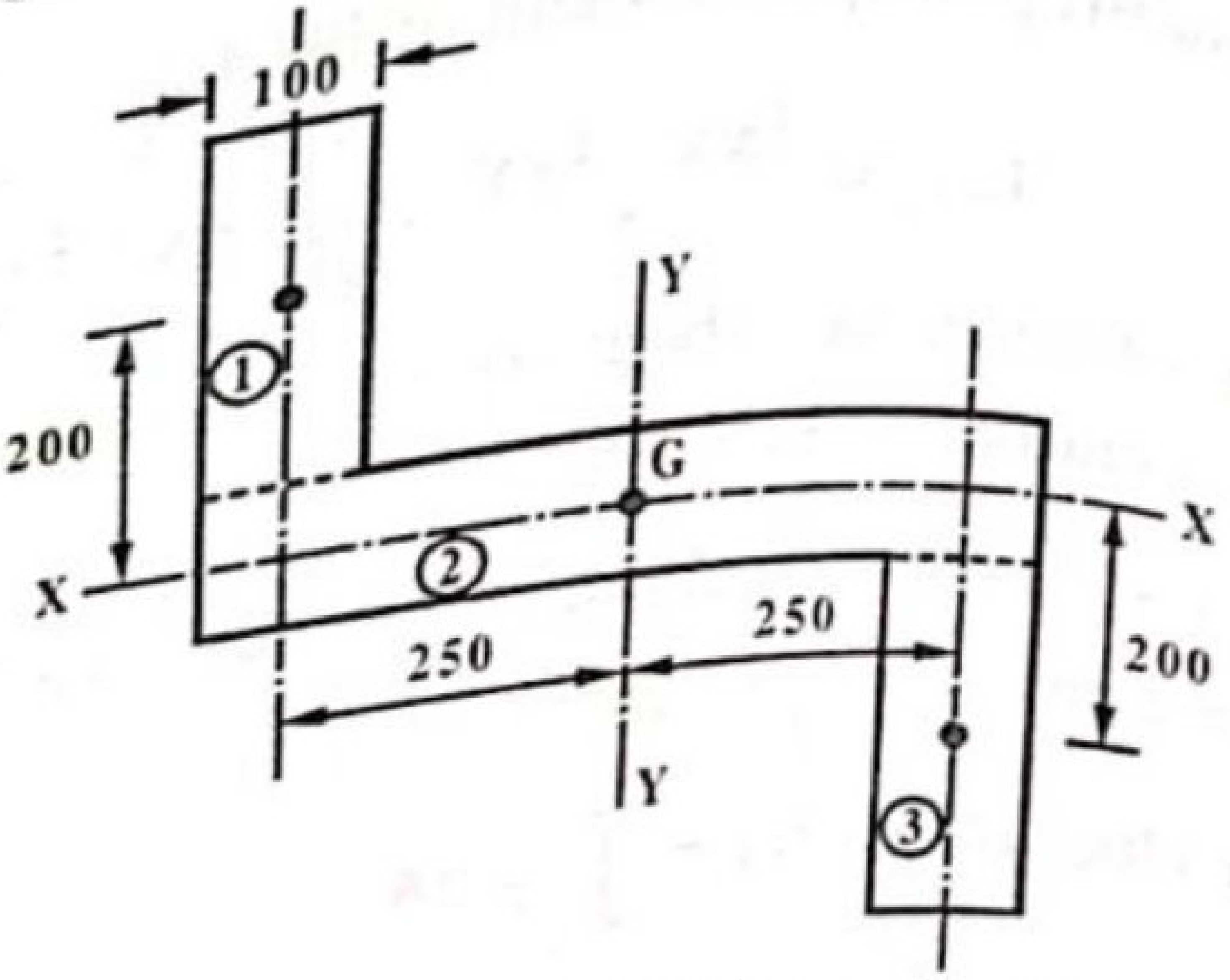


Fig. 5.33

(ii) Rectangle (2)

$$I_{XX_2} = I_{G_2} = \frac{600 \times (100)^3}{12} = 50 \times 10^6 \text{ mm}^4$$

$$I_{YY_2} = \frac{100 \times (600)^3}{12} = 1800 \times 10^6 \text{ mm}^4$$

(iii) Rectangle (3)

$$I_{XX_3} = I_{XX_1} = 1425 \times 10^6 \text{ mm}^4$$

$$I_{YY_3} = I_{YY_1} = 1900 \times 10^6 \text{ mm}^4$$

Thus, M.I. of the whole section about XX-axis,

$$I_{XX} = I_{XX_1} + I_{XX_2} + I_{XX_3}$$
$$= (1425 \times 10^6) + (50 \times 10^6) + (1425 \times 10^6)$$
$$= 2900 \times 10^6 \text{ mm}^4$$

and M.I. of the whole section about YY-axis,

$$I_{YY} = I_{YY_1} + I_{YY_2} + I_{YY_3}$$
$$= (1900 \times 10^6) + (1800 \times 10^6) + (1900 \times 10^6)$$
$$= 5600 \times 10^6 \text{ mm}^4$$

Now let us calculate the product of inertia of the entire section, which is given by

$$I_{XY} = \Sigma(I_{xy})_i + \Sigma a_i(x_i - x)(y_i - y)$$
$$i = 1, 2, 3, \text{ sections.}$$

Here I_{xy} will be zero for all three rectangles because all of them are symmetrical about their own centroidal axis. Therefore,

$$I_{XY} = [a_1(x_1 - x)(y_1 - y)] + [a_2(x_2 - x)(y_2 - y)] + [a_3(x_3 - x)(y_3 - y)]$$
$$= [(300 \times 100) \times (-250) \times 200] + [(600 \times 100) \times 0 \times 0]$$
$$+ [(300 \times 100) \times 250 \times (-200)]$$
$$= -1500 \times 10^6 - 1500 \times 10^6 = -3000 \times 10^6 \text{ mm}^4$$

Now, maximum principal moment of inertia,

$$I_{max} = \frac{I_{XX} + I_{YY}}{2} + \sqrt{\left(\frac{I_{XX} - I_{YY}}{2}\right)^2 + (I_{XY})^2}$$

$$= \frac{(2900 \times 10^6) + (5600 \times 10^6)}{2}$$

$$+ \sqrt{\left[\frac{(2900 \times 10^6) - (5600 \times 10^6)}{2}\right]^2 + (-3000 \times 10^6)^2}$$

$$= (4250 \times 10^6) + \sqrt{10.8225 \times 10^{18}}$$

$$= 4250 \times 10^6 + 3290 \times 10^6 = \mathbf{7540 \times 10^6\ mm^4}$$ **Ans.**

and minimum principal moment of inertia,

$$I_{min} = \frac{I_{XX} + I_{YY}}{2} - \sqrt{\left(\frac{I_{XX} - I_{YY}}{2}\right)^2 + (I_{XY})^2}$$

$$= 4250 \times 10^6 - 3290 \times 10^6 = \mathbf{960 \times 10^6\ mm^4}$$ **Ans.**

Prob.14. Find the product of inertia for the plane hatched area about the axes XX and YY shown in fig. 5.34. All dimensions are in mm.

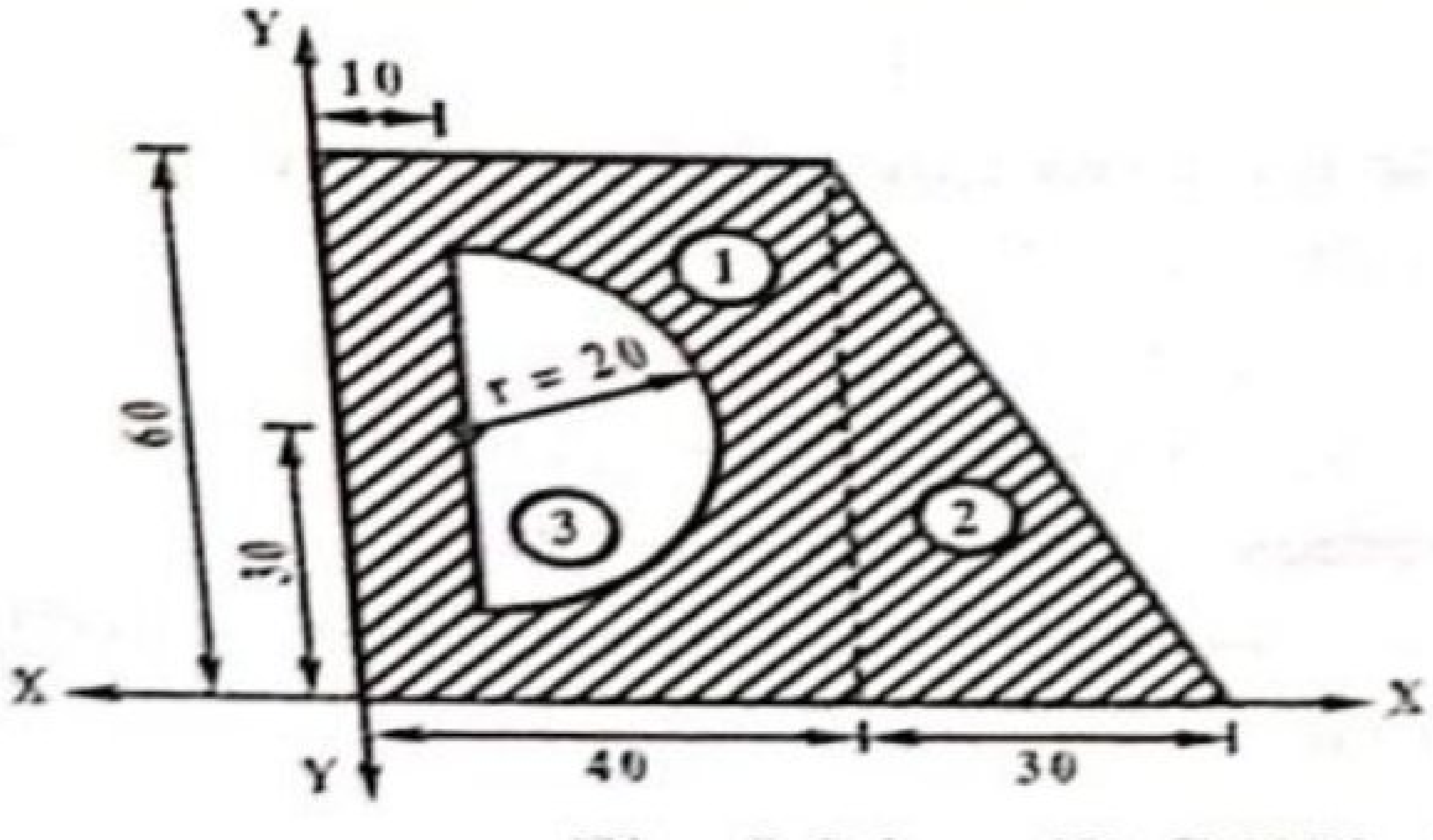


Fig. 5.34 *(R.G.P.V., March/April 2010)*

Sol. The given section can be divided into three sections, viz. rectangle, triangle and semi-circle as shown in fig. 5.34.

As product of inertia of given section has to be determined about XX and YY axes, thus product of inertia of the whole section will be

$$I_{XY} = \Sigma(I_{xy})_i + \Sigma a_i x_i y_i \qquad ....(i)$$

where i = 1, 2, 3 sections.

For rectangle,

Area, $a_1 = 40 \times 60 = 2400\ mm^2$

$x_1 = 20\ mm,\ y_1 = 30\ mm$

For rectangle the axes through its C.G. are parallel to XX and YY and are axes of symmetry, hence

$$(I_{xy})_1 = 0$$

and $$a_1x_1y_1 = 2400 \times 20 \times 30 = 144 \times 10^4 \text{ mm}^4$$

For triangle,

$$\text{Area, } a_2 = \frac{1}{2}bh = \frac{1}{2} \times 30 \times 60 = 900 \text{ mm}^2$$

$$x_2 = 40 + \frac{b}{3} = 40 + \frac{30}{3} = 50 \text{ mm}$$

$$y_2 = \frac{h}{3} = \frac{60}{3} = 20 \text{ mm}$$

$$(I_{xy})_2 = \frac{b^2h^2}{72} = \frac{(30)^2 \times (60)^2}{72} = 4.5 \times 10^4 \text{ mm}^4$$

and $$a_2x_2y_2 = 900 \times 50 \times 20 = 90 \times 10^4 \text{ mm}^4$$

For semi-circle,

$$\text{Area, } a_3 = \frac{\pi r^2}{2} = \frac{\pi \times 20^2}{2} = 628.32 \text{ mm}^2$$

$$x_3 = 10 + \frac{4r}{3\pi} = 10 + \frac{4 \times 20}{3\pi} = 18.48 \text{ mm}$$

$$y_3 = 30 \text{ mm}$$

For semi-circle the axes through its C.G. are parallel to XX and YY and are axes of symmetry, hence

$$(I_{xy})_3 = 0$$

$$a_3x_3y_3 = 628.32 \times 18.48 \times 30 = 34.83 \times 10^4 \text{ mm}^4$$

Substituting values in equation (i), we get

$$I_{XY} = [0 + 144 \times 10^4] + [4.5 \times 10^4 + 90 \times 10^4] - [0 + 34.83 \times 10^4]$$

$$= \mathbf{203.67 \times 10^4 \text{ mm}^4}$$ **Ans.**

SUPPORT REACTIONS, SHEAR FORCE AND BENDING MOMENT DIAGRAM FOR CANTILEVER AND SIMPLY SUPPORTED BEAM WITH CONCENTRATED, DISTRIBUTED LOAD AND COUPLE

Q.29. Define a beam. What are the different types of beams ?

Ans. A beam is a structural member whose one dimension is very large as compared to others two and it is subjected to a system of external forces acting at right angles to its axis. Beams are suitably supported on one or more points. Effective length of the beam between two end supports is called as its span.

Beams may be of following types –

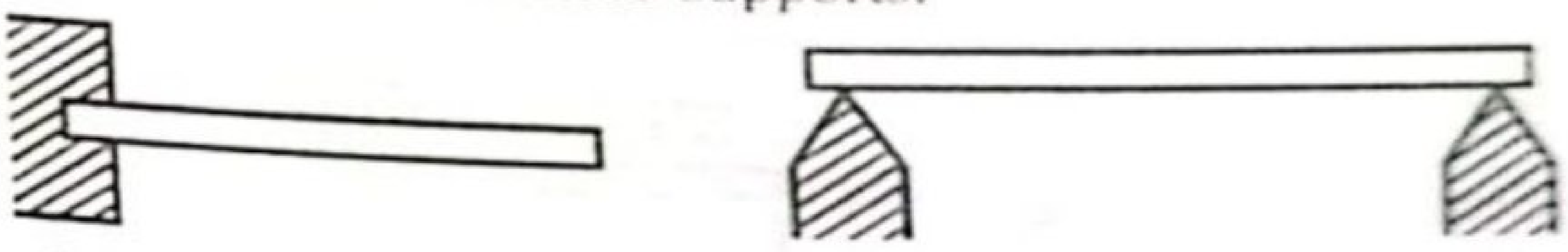
(i) *Cantilever Beam* – A beam which is fixed or built in at one end and free at the other end as shown in fig. 5.35 (a) is called as a cantilever beam. In a cantilever beam there is no reaction at its fixed end.

(ii) *Simply Supported Beam* – A beam whose both ends rests freely on supports as shown in fig. 5.35 (b) is known as a simply supported beam.

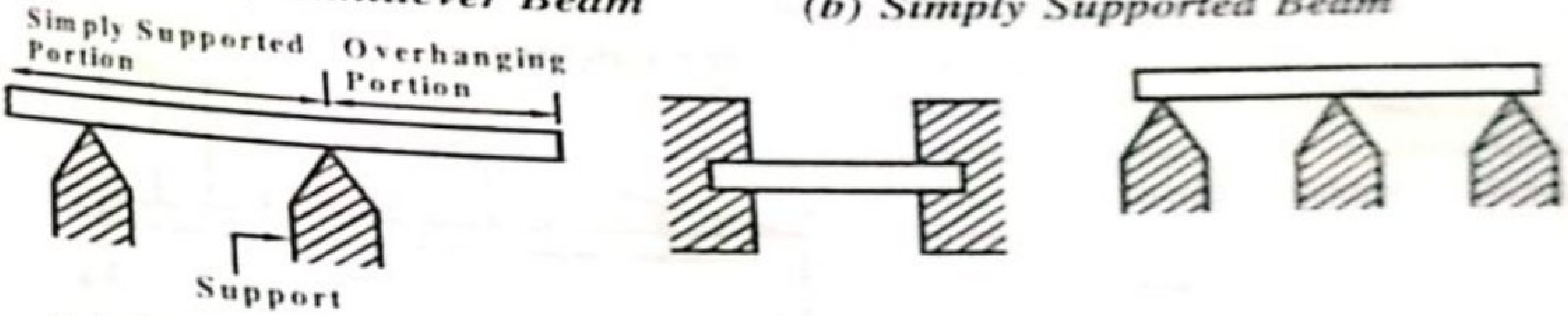
(iii) *Overhanging Beam* – If one or both of the end portions of a beam extends beyond the supports as shown in fig. 5.35 (c), then beam is known as overhanging beam.

(iv) *Fixed Beam* – If both ends of a beam are fixed or built in walls, as shown in fig. 5.35 (d), it is known as a fixed beam.

(v) *Continuous Beam* – A beam which is having more than two supports as shown in fig. 5.35 (e), is known as a continuous beam. The supports at the extreme left and right are called end supports, while all other supports are called as intermediate supports.



(a) Cantilever Beam (b) Simply Supported Beam



(c) Overhanging Beam (d) Fixed Beam (e) Continuous Beam

Fig. 5.35 Types of Beams

Q.30. *What types of loads are known to you ? Explain.*

(R.G.P.V., July 2008)

4(a)

Or

What are the different types of load acting on a beam ?

(R.G.P.V., Sept. 2009)

Ans. Some commonly applied types of transveral loads on horizontal beams are as follows –

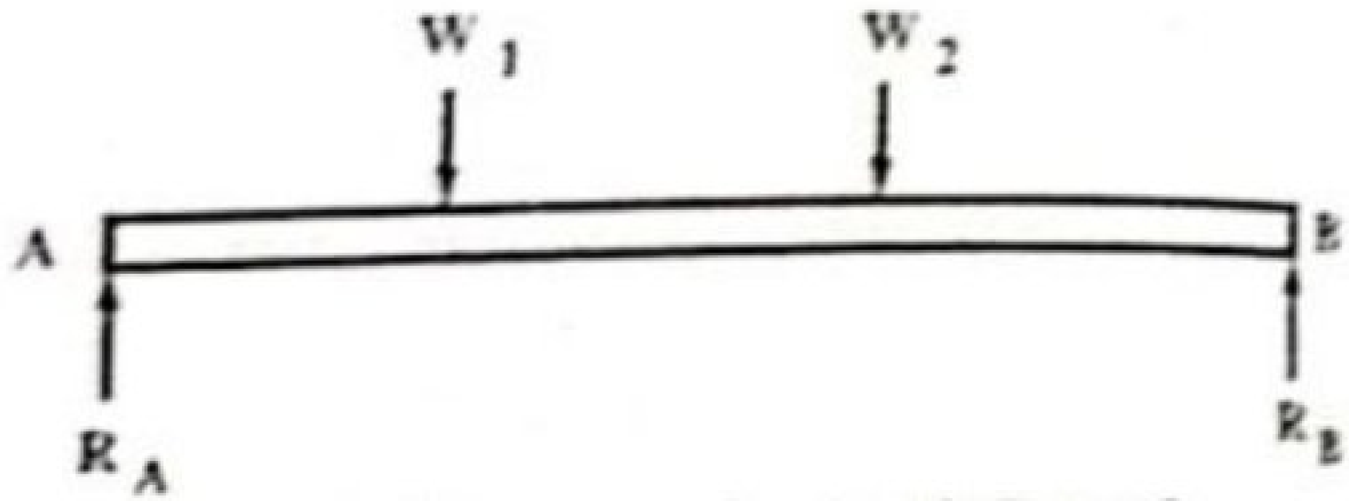
(i) ***Concentrated or Point Load*** – A load which can assumed to be acting at a point is known as a point or concentrated load. In actual practice the load is distributed over a small area, but this area is so small in comparison to the length of the beam, it may be neglected. A simply supported beam carrying point loads is shown in fig. 5.36 (a).

(ii) Uniformly Distributed Load – A load which is spread over a beam in such a manner that rate of loading remains uniform along the length of the beam (i.e. each unit length is loaded to the same extent), is known as uniformly distributed load (U.D.L.). In case of U.D.L., the total load can assumed to be act at the C.G. of the loaded portion of beam. A simply supported beam carrying a uniformly distributed load is shown in fig. 5.36 (b).

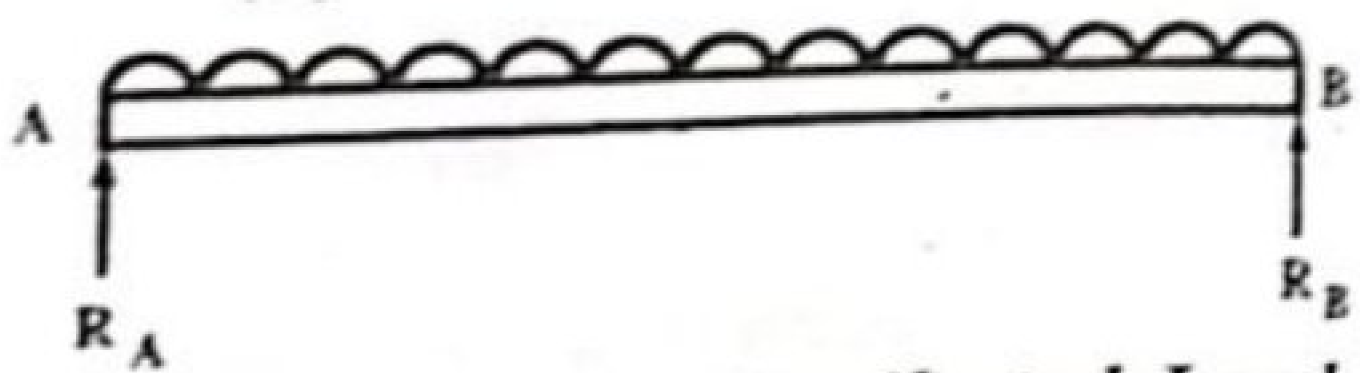
(iii) Uniformly Varying Load – A load which is spread over a beam in such a manner that rate of loading varies from point-to-point along the length of the beam as shown in fig. 5.36 (c), is known as uniformly varying load.

When load varies from zero at one end to maximum at the other end, as shown in fig. 5.36 (d), the load is known as triangular load. Total load in such cases is taken equal to the area of the triangle, and this load is assumed to be acting at the C.G. of the triangle.

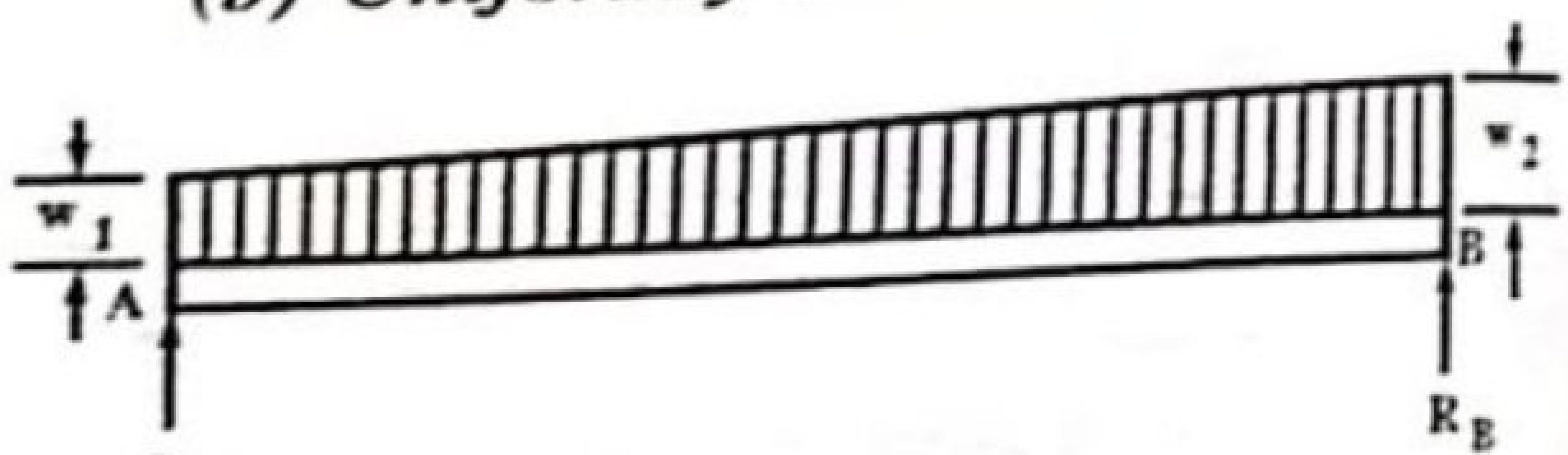
(iv) Beams Subjected to a Couple – Sometimes a beam is subjected to a clockwise or anticlockwise couple along with loads. In this case, magnitude of the couple is taken into considerations while calculating reactions. But this does not involve any kind of load.



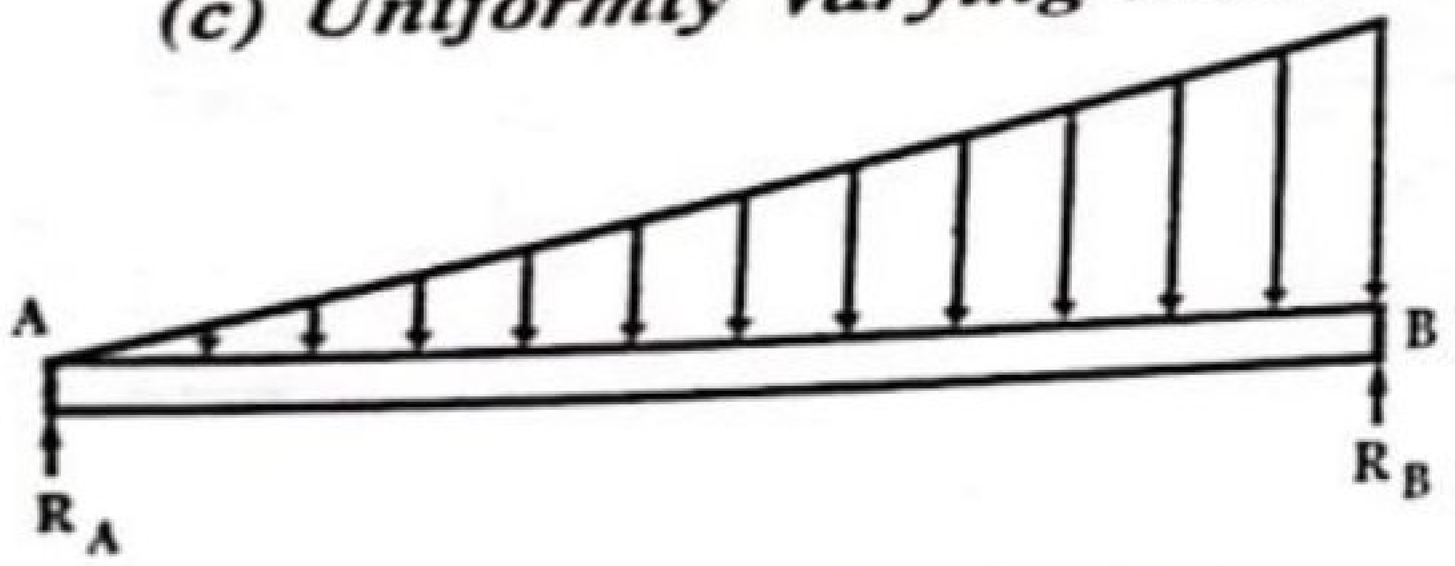
(a) Concentrated Load



(b) Uniformly Distributed Load



(c) Uniformly Varying Load



(d) Triangular Load

Fig. 5.36 Types of Loading

A beam may carry any one or a combination of two or more of above mentioned loads.

Q.31. Define various types of beams and loadings with the help of neat sketches. ***(R.G.P.V., Dec. 2012)***

Or

Show with the help of neat sketches the various types of beams and loadings. ***(R.G.P.V., June 2013)***

Ans. Refer Q.29 and Q.30.

4(b)

Q.32. Explain the term support reaction. What are the different types of supports. ***(R.G.P.V., June 2015)***

Ans. **Support Reaction –** When a body on which a number of forces are acting is supported by another body, then the second body exerts a reaction force on the first body at the points of contact. The second body is known as support and the force exerted by the second body on the first body is known as support reaction. The first body remains in equilibrium with the external forces and the support reactions, i.e. they are equal in magnitude but opposite in direction.

Types of Supports – Supports which are usually provided on beam are of the following types –

(i) ***Roller Support –*** This type of support is mainly used for steel trusses of the bridges, which have one of their end supported on rollers. These rollers allows the movement of the beam towards left or right on account of expansion or contraction, due to change of temperature. The reaction in such a support is always perpendicular to the plane of motion of rollers.

(ii) ***Hinged Support –*** In such a case the end of the beam is hinged to the support. Steel trusses, which has roller support on one end always has hinged support at other end to make the beam stable. The reaction at hinged end has two components, i.e. horizontal and vertical. Moment at hinged end is always zero.

(iii) ***Fixed Support –*** This type of support is used for fixed beams or cantilever beams, this does not allow any movement of beam. It offers three reaction components, i.e. horizontal, vertical and a moment.

Q.33. What are the various types of supports of beams ? ***(R.G.P.V., June 2014)***

Ans. Refer Q.32.

Q.34. What is shear force and bending moment ? (R.G.P.V., June 2016)

Or

Explain the following –

(i) Shear force (ii) Bending moment.

(R.G.P.V., Feb. 2007, Dec. 2010)

Ans. **Shear Force –** The shear force at any point along a loaded beam may be defined as the algebraic sum of all vertical forces acting on either side of the point on the beam. The net effect of shear force is to shear off the beam along the point at which it is acting. Shear force is taken +ve, if it produces a clockwise moment and it is taken –ve, when it produces an anticlockwise moment.

Bending Moment – Bending moment at any point along a loaded beam may be defined as the algebraic sum of the moments due to all vertical forces acting on either side of the point on the beam. The bending moment tries to bend the beam. Clockwise moments due to loads acting to the left of the section are assumed to be +ve, while anticlockwise moments are taken –ve.

Q.35. What do you mean by support reaction, explain shear force and bending moment. *(R.G.P.V., Dec. 2016)*

Ans. Refer Q.32 and Q.34.

#(P) ***Q.36. Define shear force (S.F.) and bending moment (B.M.). Give the sign conventions for S.F. and B.M.*** *(R.G.P.V., Dec. 2014)*

Ans. **Shear Force (S.F.) and Bending Moment (B.M.)** – Refer Q.34.

Sign Conventions – For drawing shear force and bending moment diagrams, first of all an arbitrary section is chosen. After that following sign conventions are used –

(i) ***Shear Force*** – Force acting in right hand side of the section in upward direction is taken negative, and force in right hand side of the section acting in downward direction is taken as positive. Similarly a force in left hand side of the section is taken positive, if it is acting in upward direction and it is taken as negative if it is acting in downward direction. This sign convention is shown in fig. 5.37.

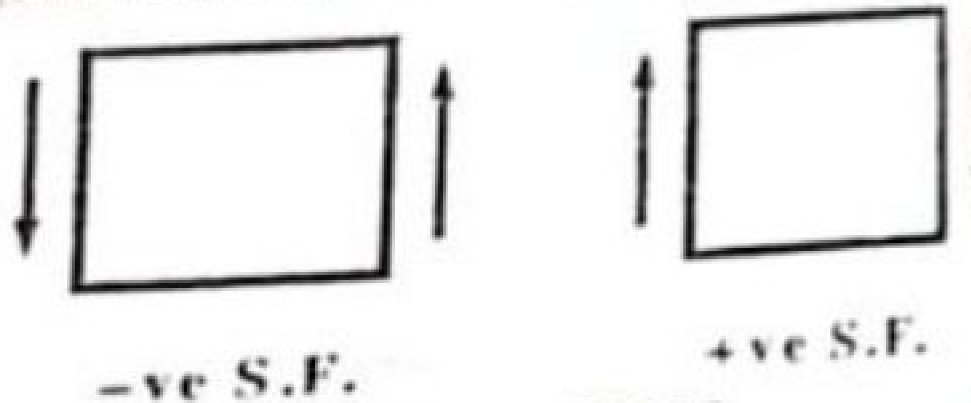


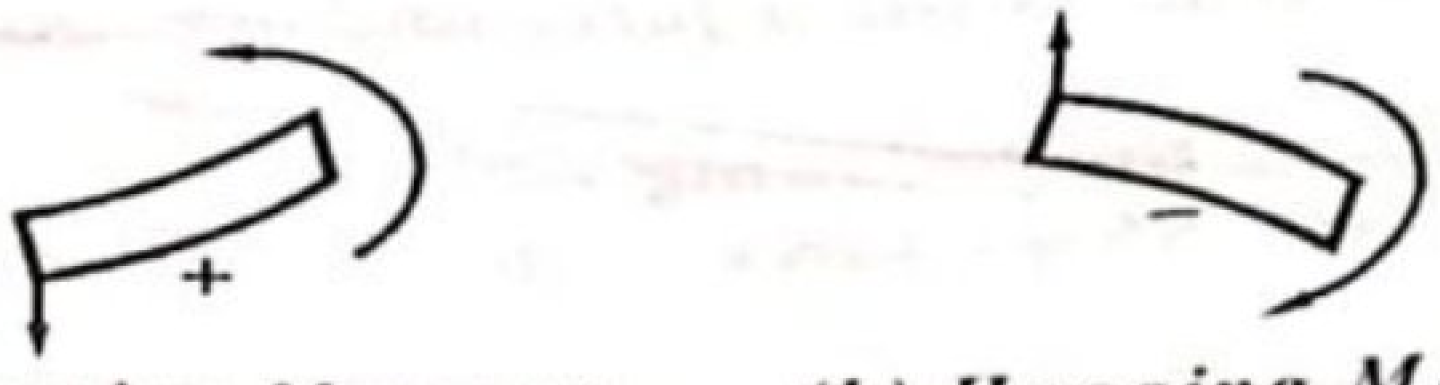
Fig. 5.37

(ii) ***Bending Moment*** – First of all remove all the loads and reactions from any one side of the section. Now introduce each load and reaction one at a time and find its effect at the section. A sagging B.M. causing concavity upwards is taken positive and a hogging bending moment is taken negative.

In general the moment due to every downward force is negative and the moment due to every upward force is positive.

Q.37. What are sagging and hogging moments ? ***(R.G.P.V., Jan./Feb. 2008)***

Ans. A B.M. causing concavity upwards is called as sagging bending [shown in fig. 5.38 (a)], while a B.M. causing convexity upwards is called as hagging bending moment [refer fig. 5.38 (b)].



(a) Sagging Moment ***(b) Hogging Moment***

Fig. 5.38

Q.38. What are shear force and bending moment diagrams ?

Ans. A shear force diagram is a diagram which shows the shear force at every section of the beam due to transverse loading on it. Its base line is equal to the span of the beam drawn on a suitable scale. For point loads S.F. diagram has straight horizontal lines, for U.D.L., it has straight inclined lines, and for uniformly varying loads it has a parabolic curve.

A bending moment diagram is a diagram which shows the bending moment at every section of the beam due to transverse loading on it. In case of a simply supported beam bending moment is zero at the ends, and for a cantilever it is zero at the free end. For point loads, B.M. diagram has straight inclined lines, for U.D.L. it has parabolic curve and for uniformly varying load it has cubic curve.

Q.39. What important points must be kept in mind while drawing the shear force and bending moment diagrams ?

Ans. The following points must be kept in mind while drawing the shear force and bending moment diagrams –

(i) First of all, consider either the left or the right hand side of the section.

(ii) Add the forces (including reaction) normal to the beam on one of the side. If right hand side of the section is chosen, a force acting downwards is taken positive while a force acting upwards is negative.

If the left hand side of the section is chosen, a force acting upwards is taken positive while a force acting downwards is negative.

(iii) The positive values of shear force and bending moment are plotted above the base line, and negative values below the base line.

(iv) The shear force diagram will decrease or increase suddenly shown by a vertical straight line at a section when there is a vertical point load.

(v) The shear force between any two vertical loads will be constant and hence the shear force diagram between two vertical loads will be a horizontal line.

(vi) The bending moment at the two supports of a simply supported beam and also at the free end of a cantilever will be zero.

Q.40. What is the point of contraflexure ? ***[R.G.P.V., June 2008(N)]***

Or

What is point of contraflexure ? State and explain. (R.G.P.V., June 2009)

Or

What do you mean by point of contraflexure ?

(R.G.P.V., Sept. 2009, June 2010)

Ans. An overhanging beam can be considered as a combination of a simply supported beam and a cantilever beam. As we know that the bending moment in a cantilever beam is negative, whereas that in a simply supported beam is positive. Thus, in an overhanging beam, there will be a point, where the bending moment will change its sign from negative to positive or vice-versa. Such a point where the bending moment changes sign is known as ***point of contraflexure.***

The point of contraflexure is also called the point of inflexion or virtual hinge. The point of contraflexure can be determined by equating the bending moment equation in terms of x equal to zero for part of beam length where bending moment is likely to change sign.

Q.41. Establish the relationship between rate of loading, shear force and bending moment with usual notations. ***(R.G.P.V., Dec. 2006)***

Or

Deduce the relationship between bending moment and shear force at a cross-section of a beam. ***[R.G.P.V., June 2006, 2008 (O)]***

Ans. Consider a beam AB, as shown in fig. 5.39 carrying a uniformly distributed load of w per unit length.

Now consider the equilibrium of the portion of beam between sections 1-1 and 2-2. a short length δx of beam at a distance x from end A.

The forces and moments acting on the length δx of the beam are –

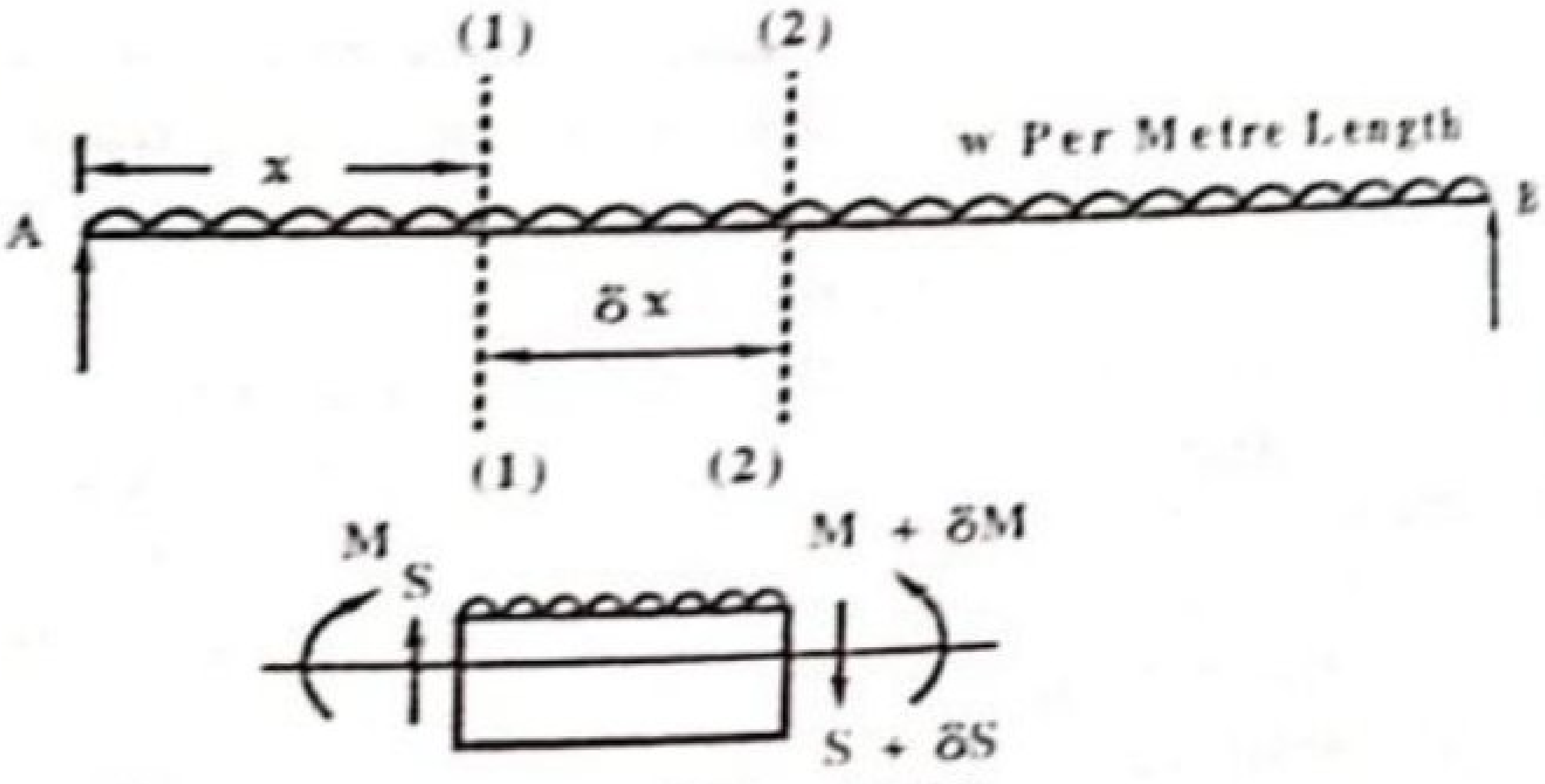


Fig. 5.39

(i) The force S acting vertically upwards at the section 1-1.

(ii) The force S + δS acting vertically downwards at the section 2-2.

(iii) The load w × δx acting downwards.

(iv) The moments M and M + δM acting at sections 1-1 and 2-2 respectively.

Since the portion of the beam of length δx is in equilibrium, therefore ΣV = 0, i.e.

$$S - (S + \delta S) + w\delta x = 0$$

$$\delta S = w\delta x$$

or

$$w = \frac{\delta S}{\delta x} = \frac{dS}{dx} \qquad \text{...(i)}$$

This is the relationship between rate of loading and shear force. This equation shows that the rate of loading is equal to the rate of change of shear force.

Taking the moments of the forces and couples about the section 2-2, we get

$$M - w.\delta x.\frac{\delta x}{2} - (M + \delta M) + S.\delta x = 0$$

Neglecting the higher powers of small quantities, we get

$$S.\delta x = \delta M$$

$$\therefore \qquad S = \frac{\delta M}{\delta x} = \frac{dM}{dx} \qquad \text{...(ii)}$$

The above equation shows that the rate of change of bending moment is equal to the shear force at the section.

The B.M., M shall be maximum or minimum when $\frac{dM}{dx} = 0$, i.e. $S = 0$.

Thus at the section where S.F. is zero or changes sign, the B.M. is either maximum or minimum.

Combining equations (i) and (ii), we get

$$w = \frac{dS}{dx} = \frac{d^2M}{dx^2} \qquad \text{....(iii)}$$

Equations (i), (ii) and (iii) can also be written as

$$S = \int w\,dx;\ M = \int S\,dx$$

and

$$M = \int\left(\int w\,dx\right)dx$$

NUMERICAL PROBLEMS

Prob.15. Draw S.F. and B.M. diagram for cantilever beam loaded as shown in fig. 5.40 (a). Also locate the position of point of contraflexure. ***(R.G.P.V., Dec. 2014)***

Sol. **S.F. Calculations –**

S.F. at C,

$$S_C = 10 \text{ kN}$$

Between B and C, S.F. will vary linearly and at B it will be

$$S_B = 10 + 8 = 18 \text{ kN}$$

S.F. diagram is shown in fig. 5.40 (b).

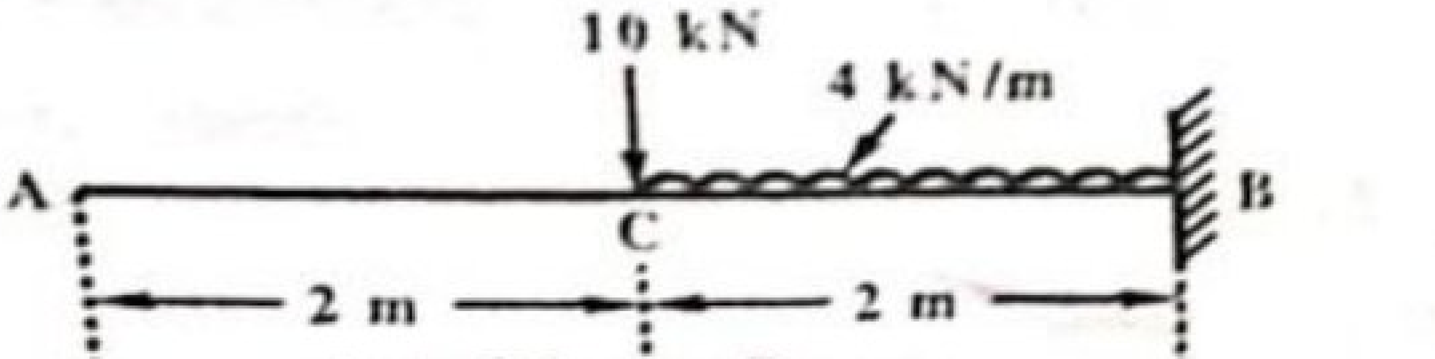
B.M. Calculations –

B.M. at A and C will be zero i.e. $M_A = M_C = 0$

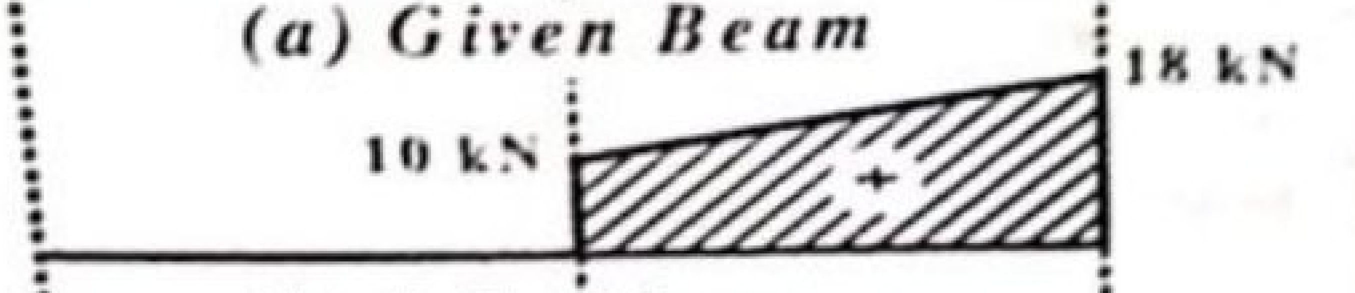
B.M. at B,

$$M_B = -10 \times 2 - 4 \times 2 \times 1$$
$$= -20 - 8 = -28 \text{ kN-m}$$

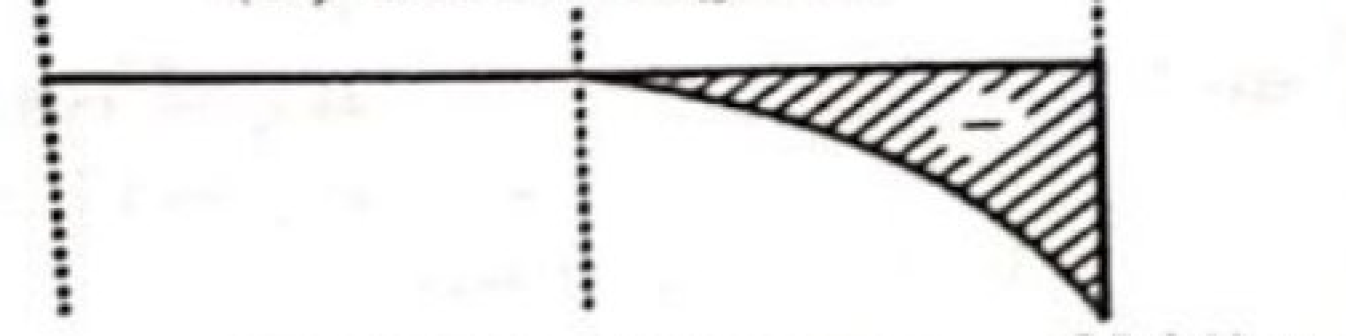
The B.M. diagram is shown in fig. 5.40 (c).



(a) Given Beam



(b) S.F. Diagram



(c) B.M. Diagram

Fig. 5.40

Point of Contraflexure – Since B.M. does not change in direction so there will be no given point of contraflexure.

Prob.16. Draw shear force and bending moment diagram for a cantilever beam loaded as shown in fig. 5.41 (a). ***(R.G.P.V., June 2016)***

Sol. **S.F. Calculations –**

S.F. at C, $S_C = 0$

Between B and C, S.F. will vary linearly and at B it will be

$$S_B = 5 \times 4 = 20 \text{ kN}$$

Between B and A, S.F. will again vary linearly and at A it will be

$$S_A = S_B + 10 \times 3$$
$$= 20 + 30 = 50 \text{ kN}$$

S.F. diagram is shown in fig. 5.41 (b).

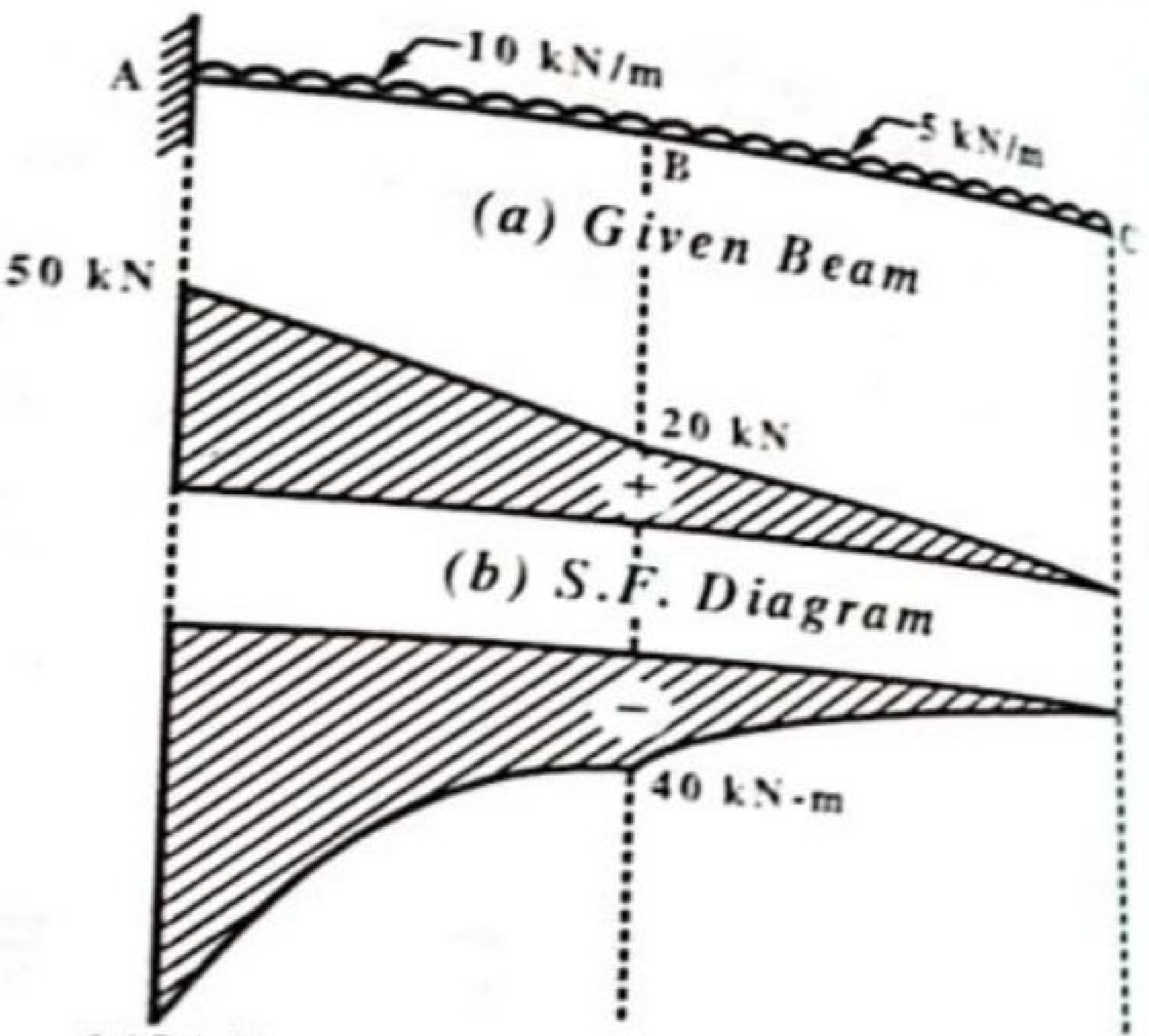
B.M. Calculations –

B.M. at free end of cantilever will be zero, i.e.

$$M_C = 0$$

B.M. at B,

$$M_B = -5 \times 4 \times 2$$
$$= -40 \text{ kN-m}$$



(a) Given Beam

(b) S.F. Diagram

(c) B.M. Diagram

Fig. 5.41

B.M. at A,

$$M_A = -5 \times 4 \times 5 - 10 \times 3 \times 1.5 = -145 \text{ kN-m}$$

B.M. diagram is shown in fig. 5.41 (c).

Prob.17. Draw the shear force and bending moment diagrams for the beam loaded and supported as shown in fig. 5.42 (a). (R.G.P.V., Dec. 2012)

Sol. Let R_A and R_D be the reactions at supports A and D respectively. Taking moments about support A, we get

$$R_D \times 8 = \left(1 \times 2 \times \frac{2}{2}\right) + 10 \times 2 + 4 \times 4 = 38 \text{ kN}$$

$$\therefore \quad R_D = 4.75 \text{ kN}$$

and

$$R_A = \text{Total vertical load} - R_D$$
$$= (1 \times 2) + 10 + 4 - 4.75 = 11.25 \text{ kN}$$

S.F. Calculations

S.F. at D, $S_D = -R_D = -4.75$ kN

This S.F. will remain constant between D and C, and at C it will suddenly change to

$$S_C = -4.75 + 4 = -0.75 \text{ kN}$$

S.F. just right of B = – 0.75 kN

S.F. just left of B = – 0.75 + 10 = 9.25 kN

The S.F. between B and A will vary linearly and at A, it will become,

$$S_A = 9.25 + 1 \times 2 = 11.25 \text{ kN}$$

The S.F. diagram is shown in fig. 5.42 (b).

B.M. Calculations

B.M. at both the supports will be i.e.

$$M_A = M_D = 0$$

B.M. at C.

$$M_C = 4.75 \times 4 = 19 \text{ kN-m}$$

B.M. at B.

$$M_B = 4.75 \times 6 - 4 \times 2$$
$$= 20.5 \text{ kN-m}$$

B.M. at any section between B and A at a distance x from end A is given by

$$M_X = 11.25\ x - 1.x.\frac{x}{2}$$
$$= 11.25x - \frac{x^2}{2}$$

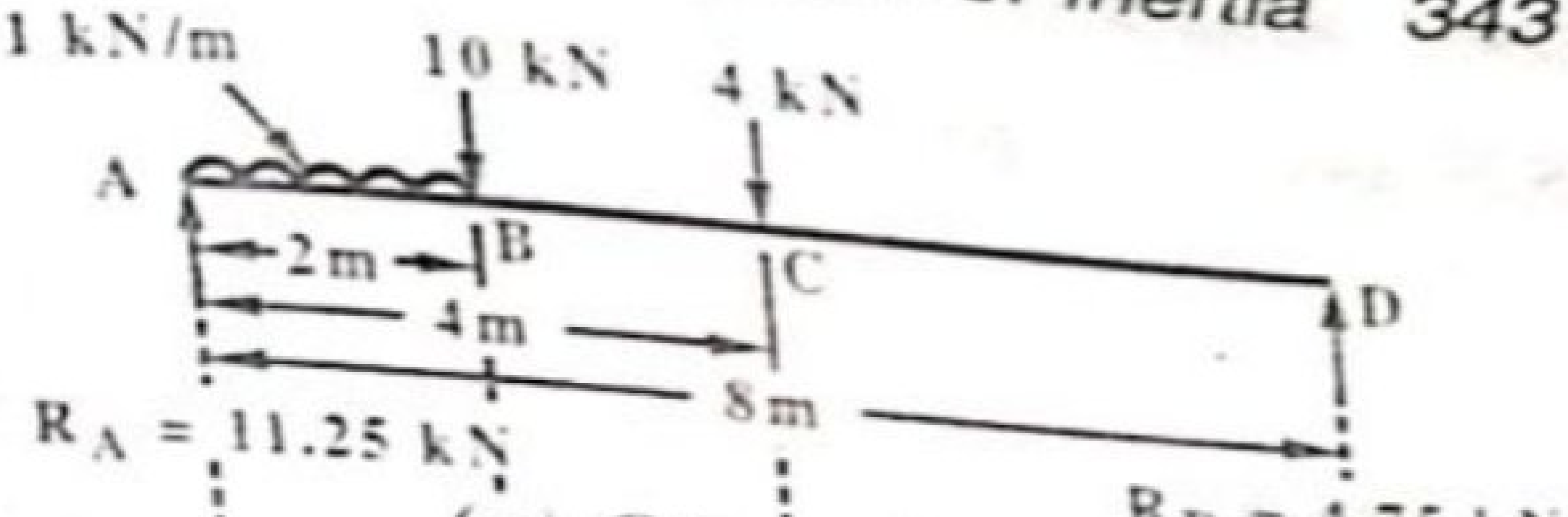
At x = 2 m, i.e. at B,

$$M_B = 11.25 \times 2 - \frac{(2)^2}{2} = 20.5$$

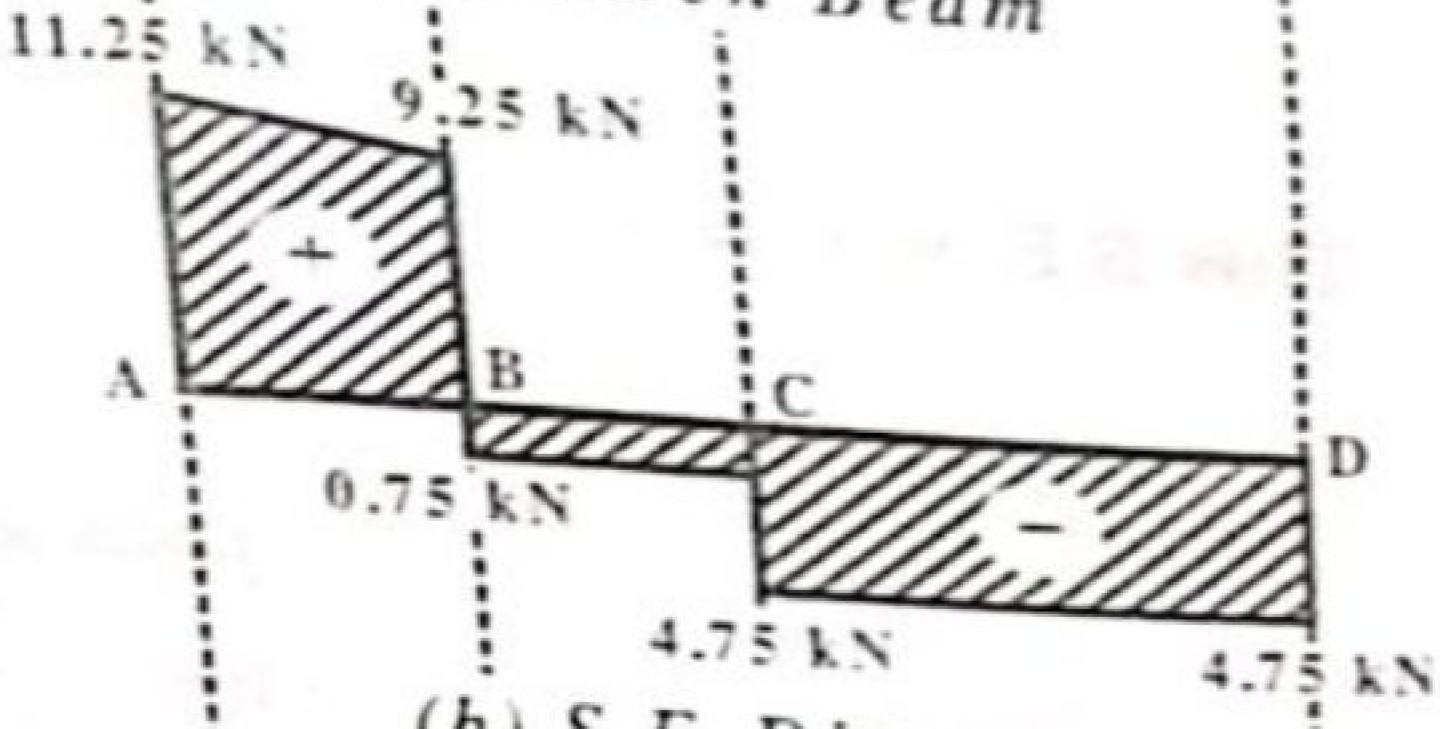
kN-m (same as before)

At x = 0, i.e. at A,

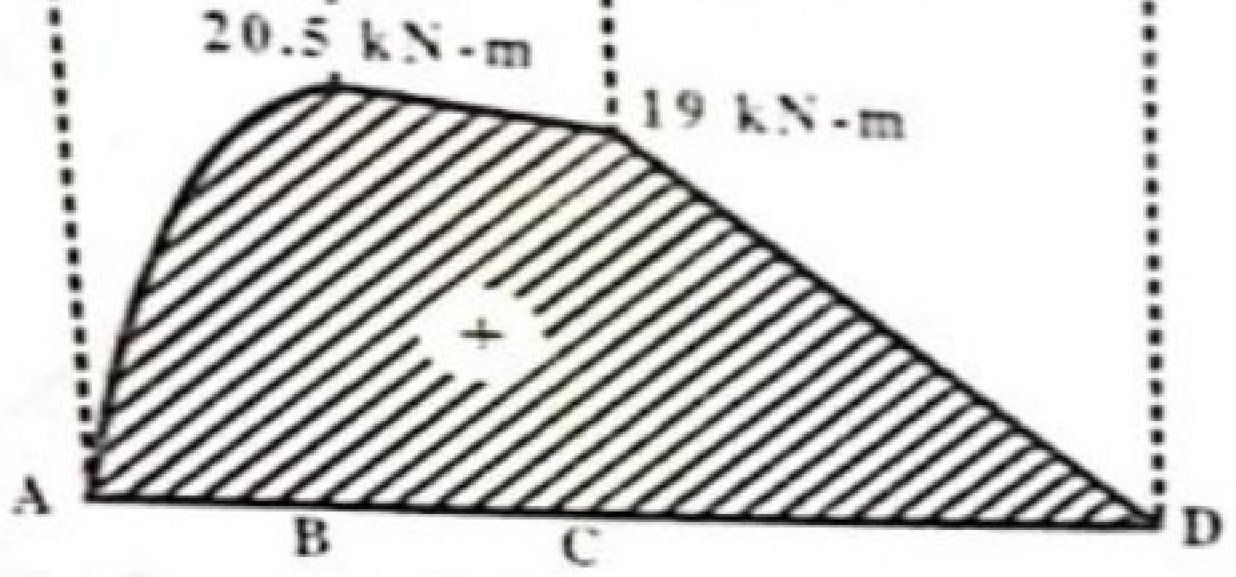
$$M_A = 0$$



(a) Given Beam



(b) S.F. Diagram



(c) B.M. Diagram

Fig. 5.42

The B.M. diagram is shown in fig. 5.42 (c).

Prob.18. Draw the shear force and bending moment diagram for the beam loaded as shown in fig. 5.43 (a). Clearly mark the position of maximum bending moment and determine its value. ***(R.G.P.V., June 2013)***

Sol. Let R_A and R_B be the reactions at supports A and B respectively.

Taking moments about end A, we get

$$R_B \times 6 = 1 \times 1 + (2 \times 2 \times 3) + 4 \times 5 = 33$$
$$\therefore \quad R_B = 5.5 \text{ kN}$$
and
$$R_A = \text{Total vertical load} - R_B$$
$$= 1 + (2 \times 2) + 4 - 5.5 = 3.5 \text{ kN}$$

S.F. Calculations

S.F. at B, $S_B = -R_B = -5.5$ kN

This S.F. will remain constant between B and F, and at F it will suddenly change to

$$S_F = -5.5 + 4 = -1.5 \text{ kN}$$

This S.F. will again remain constant between F and E, and between E and D it will vary linearly. At any point between E and D, at a distance x from B, S.F. is given by,

$$S_X = -R_B + 4 + 2(x - 2)$$

$$= -5.5 + 4 + 2x - 4 = 2x - 5.5 \qquad \text{...(i)}$$

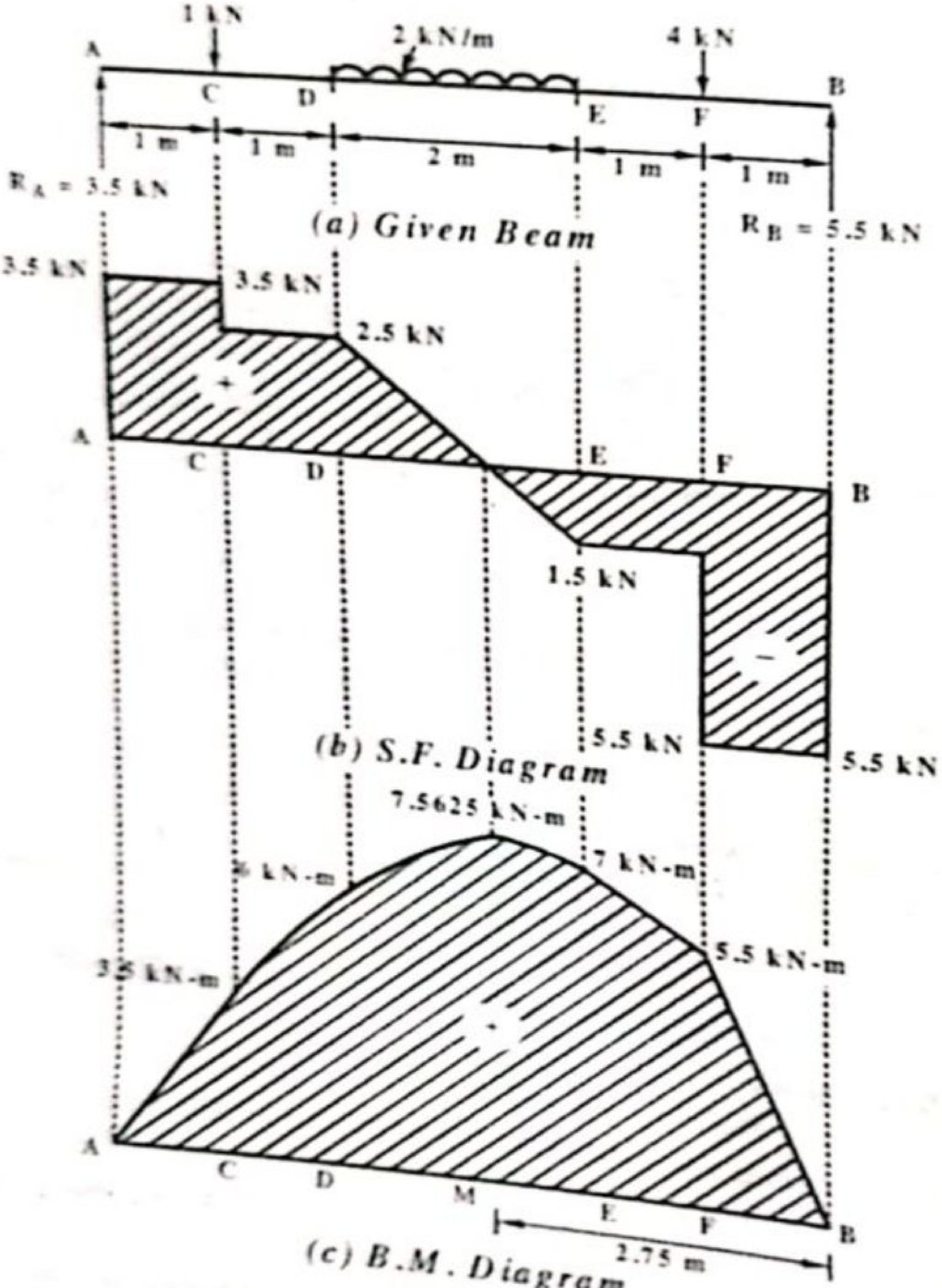
At $x = 2$ m, i.e. at E, $S_E = 4 - 5.5 = -1.5$ kN

and at $x = 4$ m, i.e. at D, $S_D = 8 - 5.5 = 2.5$ kN

S.F. at C, $S_C = 2.5 + 1 = 3.5$ kN

This S.F. will remain constant between C and A, and

$$S_A = 3.5 \text{ kN}$$



(a) Given Beam

(b) S.F. Diagram

(c) B.M. Diagram

Fig. 5.43

S.F. changes its sign between E and D, point of zero S.F. can be obtained by equating S_X to zero, i.e.

$$2x - 5.5 = 0$$

$$\therefore \quad x = 2.75 \text{ m from B}$$

This point is shown by point M in S.F. diagram shown in fig. 5.43 (b).

B.M. Diagram

B.M. at both the supports will be zero, i.e. $M_A = M_B = 0$

B.M. at F, $M_F = 5.5 \times 1 = 5.5$ kN-m

B.M. at E, $M_E = 5.5 \times 2 - 4 \times 1 = 7$ kN-m

B.M. at any point between E and D at a distance x from end B is given by,

$$\begin{aligned} M_X &= 5.5\,x - 4(x-1) - 2\frac{(x-2)^2}{2} \\ &= 5.5\,x - 4x + 4 - (x-2)^2 \\ &= 1.5x + 4 - (x-2)^2 \qquad \text{...(ii)} \end{aligned}$$

At x = 2 m, i.e. at E,

$$M_E = 1.5 \times 2 + 4 - 0 = 7 \text{ kN-m (same as before)}$$

At x = 4 m, i.e. at D,

$$\begin{aligned} M_D &= 1.5 \times 4 + 4 - (4-2)^2 \\ &= 6 + 4 - 4 = 6 \text{ kN-m} \end{aligned}$$

B.M. at C, $M_C = R_A \times 1 = 3.5 \times 1 = 3.5$ kN-m

Maximum B.M. will occur at a point of zero S.F., i.e. at x = 2.75 m from B. Thus, from equation (ii),

$$\begin{aligned} M_{max} &= (1.5 \times 2.75) + 4 - (2.75 - 2)^2 \\ &= \mathbf{7.5625 \text{ kN-m}} \end{aligned}$$

Ans.

The B.M. diagram is shown in fig. 5.43 (c).

#⑥

Prob.19. Draw the shear force and bending moment diagrams for the beam shown in fig. 5.44 (a) ***(R.G.P.V., Dec. 2013)***

Sol. S.F. Calculation –

S.F. at D, $S_D = 10$ kN

The S.F. will vary linearly between D and C, and at any section between D and C at a distance x from D, S.F. is given by,

$$S_X = 10 + 10x$$

At D, x = 0, hence $S_D = 10$ kN

At C, x = 1m, hence $S_C = 10 + 10 \times 1 = 20$ kN

This S.F. will remain constant between C and A, as there is no vertical loading.

S.F. diagram for the beam is shown in fig. 5.44 (b).

B.M. Calculations –

B.M. at free end, i.e. at D will be zero, thus

$M_D = 0$

B.M. at C.

$M_C = -10 \times 1 - 10 \times 1 \times \frac{1}{2}$

$= -15$ kN-m

B.M. at just right hand side of B

$= -10 \times 2 - 10 \times 1 \left(1 + \frac{1}{2}\right)$

$= -20 - 15$

$= -35$ kN-m

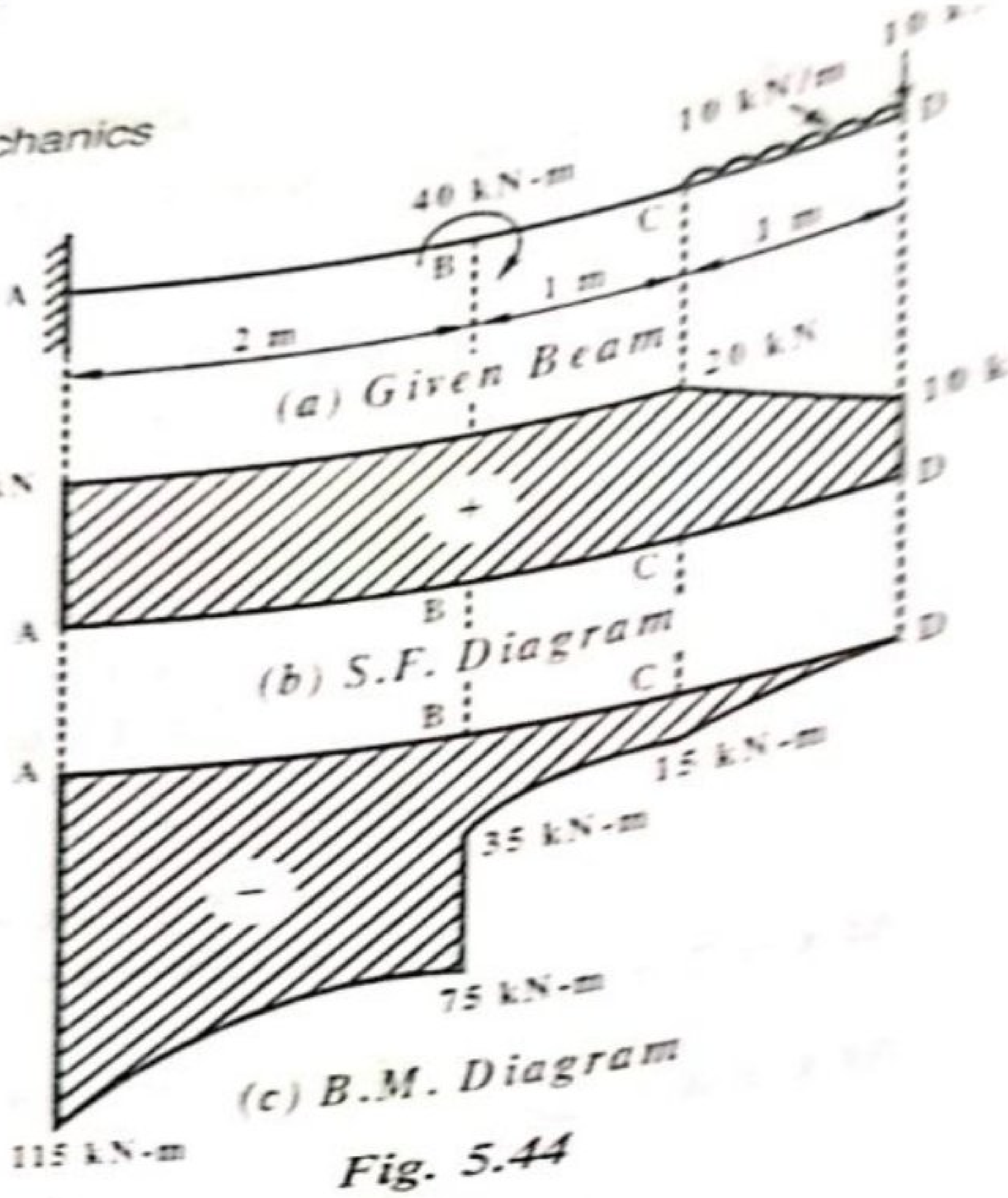
At B there is a couple of 40 kN-m (clockwise), hence B.M. at just left hand side of B will be

$= -35 - 40 = -75$ kN-m

B.M. at A.

$M_A = -10 \times 4 - 10 \times 1 \times \left(3 + \frac{1}{2}\right) - 40$

$= -40 - 35 - 40 = -115$ kN-m



(a) Given Beam

(b) S.F. Diagram

(c) B.M. Diagram

Fig. 5.44

The B.M. diagram for the beam is shown in fig. 5.44 (c)

Prob.20. Draw the shear force and bending moment diagrams for the beam shown in fig. 5.45 (a). ***(R.G.P.V., Dec. 2013)***

Sol. Let R_A and R_B be the vertical reactions at supports A and B respectively.

Taking moments about support A, we get

$$R_B \times 9 = 80 \times 2 + 60 + 120$$

$$= 340 \text{ kN-m}$$

$\therefore$ $R_B = 37.78$ kN

and R_A = Total vertical load – R_B

$= 80 - 37.78 = 42.22$ kN

S.F. Calculations

S.F. at B, $S_B = -R_B = -37.78$ kN

This S.F. will remain constant between B and C, as there is no vertical loading between B and C. At C, it will change suddenly to

$S_C = -37.78 + 80 = 42.22$ kN

This S.F. will remain constant upto A.

The S.F. diagram for the beam is shown in fig. 5.45 (b).

B.M. Calculations –

B.M. at both the supports will be zero, i.e.

$M_A = M_B = 0$

B.M. at just left hand side of E

$= 37.78 \times 3$

$= 113.34$ kN-m

B.M. at just right hand side of E

$= 113.34 - 120$

$= -6.66$ kN-m

B.M. at just left hand side of D

$= 37.78 \times 5 - 120$

$= 68.9$ kN-m

B.M. at just right hand side of D

$= 68.9 - 60 = 8.9$ kN-m

B.M. at C,

$M_C = 37.78 \times 7 - 120 - 60$

$= 84.44$ kN-m

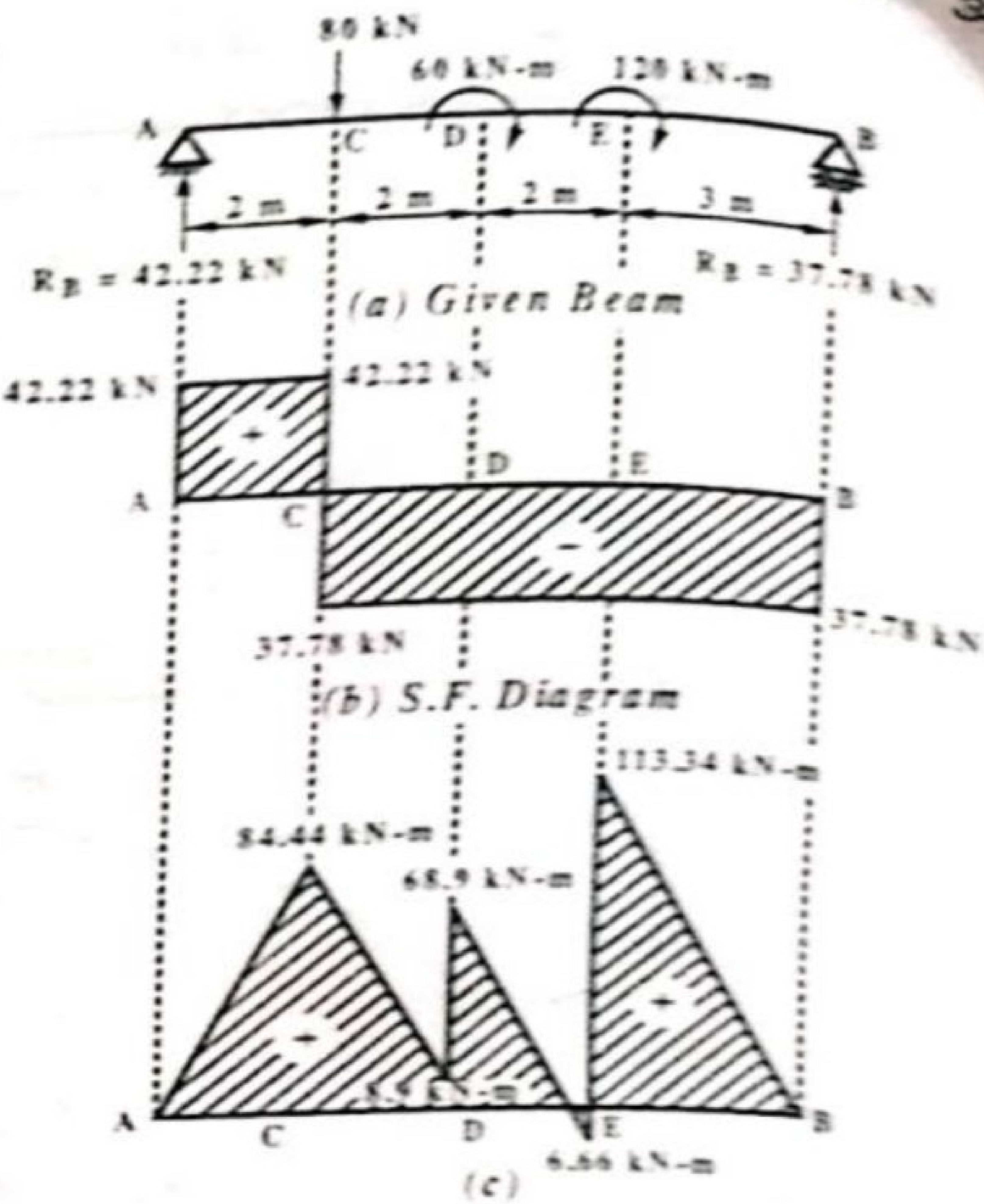


Fig. 5.45

The B.M. diagram of the beam is shown in fig. 5.45 (c).

Prob.21. Draw the S.F. and B.M. diagrams for beam shown in fig. 5.46. Find out the position and magnitude of maximum moment.

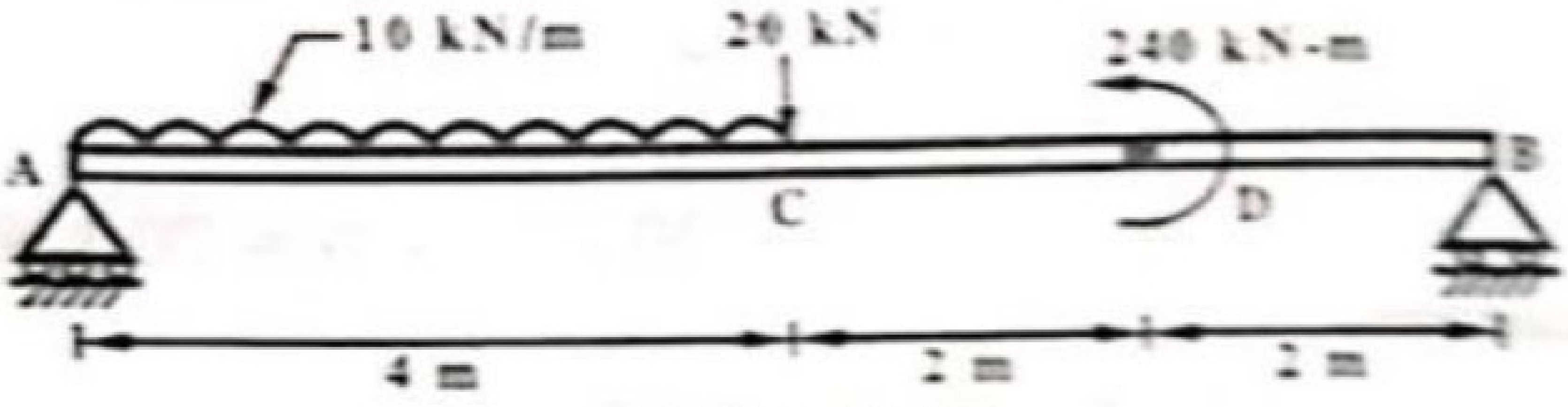


Fig. 5.46

(R.G.P.V., Dec. 2011, June 2012)

Sol. Let R_A and R_B be the reactions at supports A and B respectively. Taking moments about the support A, we get

$$R_B \times 8 = \left(10 \times 4 \times \frac{4}{2}\right) + 20 \times 4 - 240 = -80$$

$$\therefore \qquad R_B = \frac{-80}{8} = -10 \text{ kN}$$

–ve sign indicates R_B will act downward as shown in fig. 5.47 (a).

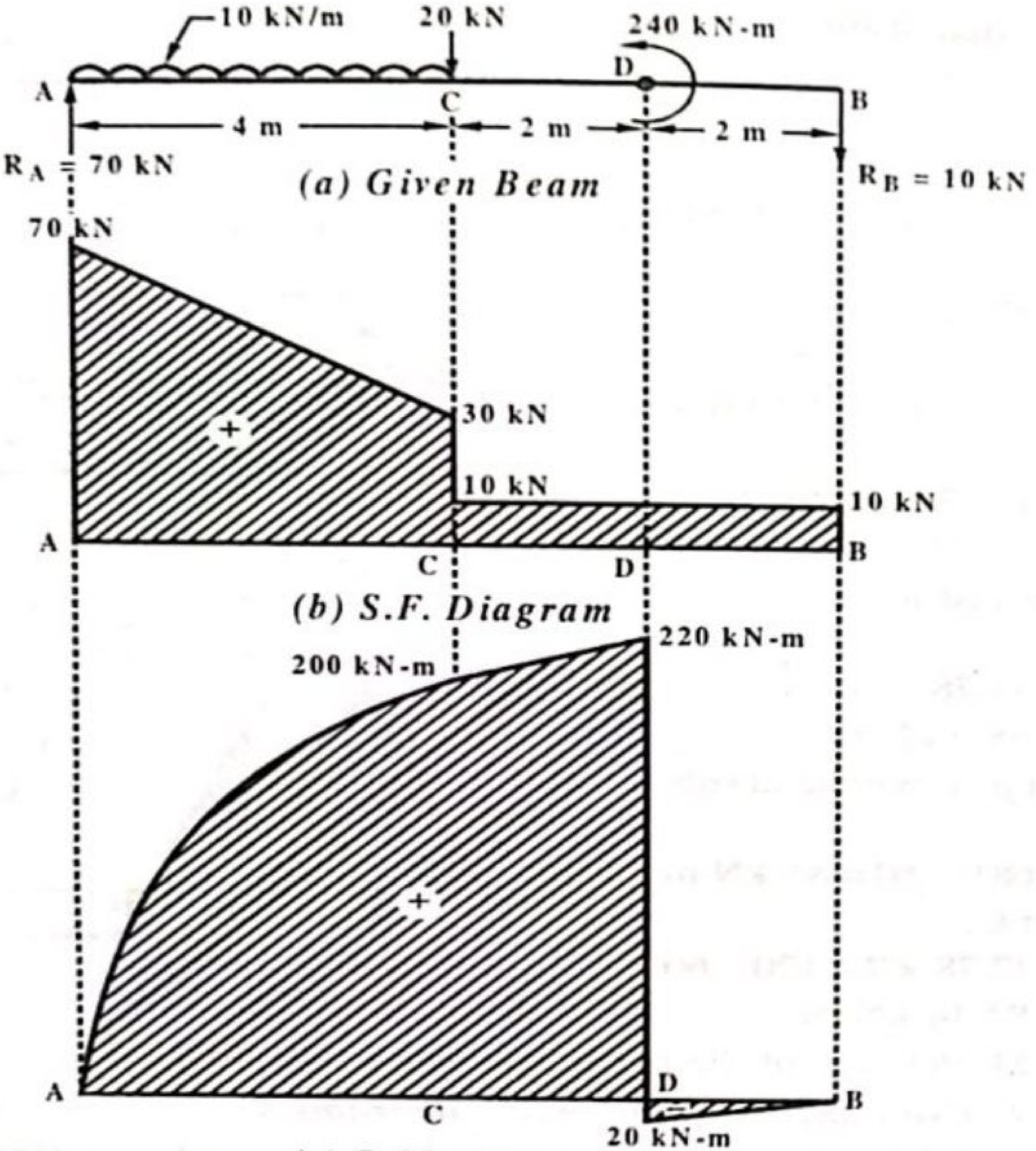


Fig. 5.47

Now R_A = Total vertical load $- R_B$

$$= (10 \times 4) + 20 - (-10) = 70 \text{ kN}$$

S.F. Calculations

S.F. at B, $S_B = -R_B = 10$ kN

S.F. between B and C remains constant as there is no vertical load between B and C. At C it will suddenly change to

$$= 10 + 20 = 30 \text{ kN}$$

S.F. will vary linearly between C and A. At any section X at a distance x from end A, S.F. will be given by,

$$S_X = R_A - 10x = 70 - 10x$$

At $x = 4$ m, i.e. at C, $S_C = 70 - 10 \times 4 = 30$ kN

At $x = 0$, i.e. at A, $S_A = 70$ kN

The S.F. diagram for the beam is shown in fig. 5.47 (b).

B.M. Calculations

B.M. at both supports will be zero, i.e.

$$M_A = M_B = 0$$

B.M. at R.H.S. of $D = -10 \times 2 = -20$ kN-m

This B.M. will suddenly change due to the anticlockwise couple of 240 kN-m. The B.M. just left of D will be

$$= -20 + 240 = 220 \text{ kN-m}$$

B.M. at C, $M_C = -10 \times 4 + 240 = 200$ kN-m

B.M. at any section X-X between C and A, at a distance x from A will be given by,

$$M_X = 70x - 10.x.\frac{x}{2} = 70x - 5x^2$$

At x = 4 m, i.e. at C, $M_C = (70 \times 4) - [(5 \times (4)^2]$

$$= 200 \text{ kN-m (same as before)}$$

At x = 0, i.e. at A, $M_A = 0$

The B.M. diagram is shown in fig. 5.47 (c). As shown in B.M. diagram, maximum bending moment is 220 kN-m, which occurs at point D, thus,

M_{max} = **220 kN-m at 6 m from A** **Ans.**

Prob.22. A beam 5.0 m long and simply supported at each end, has a uniformly distributed load of 1000 N/m extending from the left to a point 2.0 m away. There is also a clockwise couple of 1500 N-m applied at the centre of the beam. Draw the S.F and B.M. diagram for the beam.

(R.G.P.V., June 2015)

Sol. Given beam as shown in fig. 5.48 (a).

Let R_A and R_C be the reactions at supports A and C respectively.

Taking moments about the support A, we get

$$R_C \times 5 = 1000 \times 2 \times 1 + 1500$$

$$R_C = \frac{3500}{5} = 700 \text{ N}$$

Now R_A = Total vertical load – R_C

$$= 2000 - 700 = 1300 \text{ N}$$

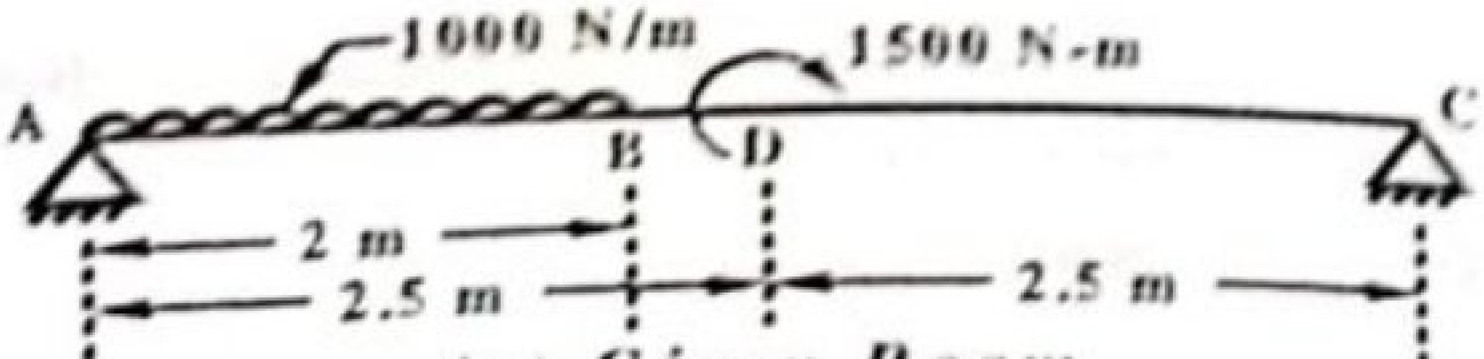
S.F. Calculations –

S.F. at C, $S_C = -R_C = -700$ N

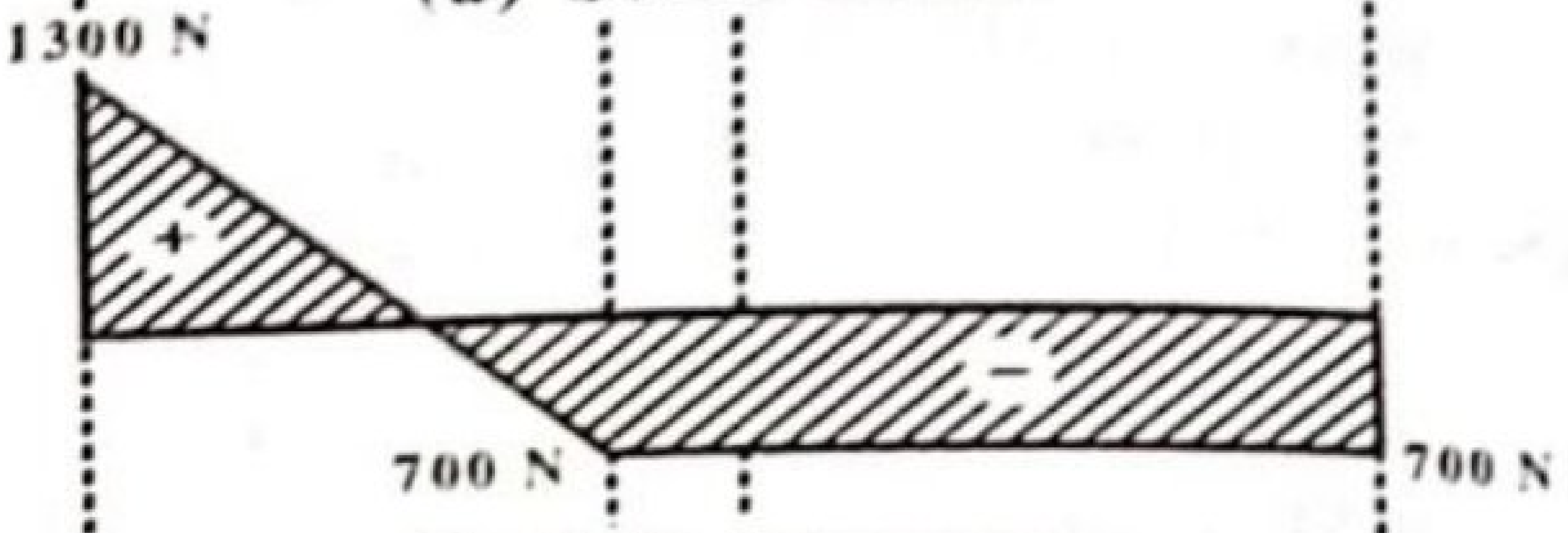
S.F. between B and C remains constant as there is no vertical load between B and C.

S.F. will vary linearly between B and A. At any section X at a distance x from end A, S.F. will be given by,

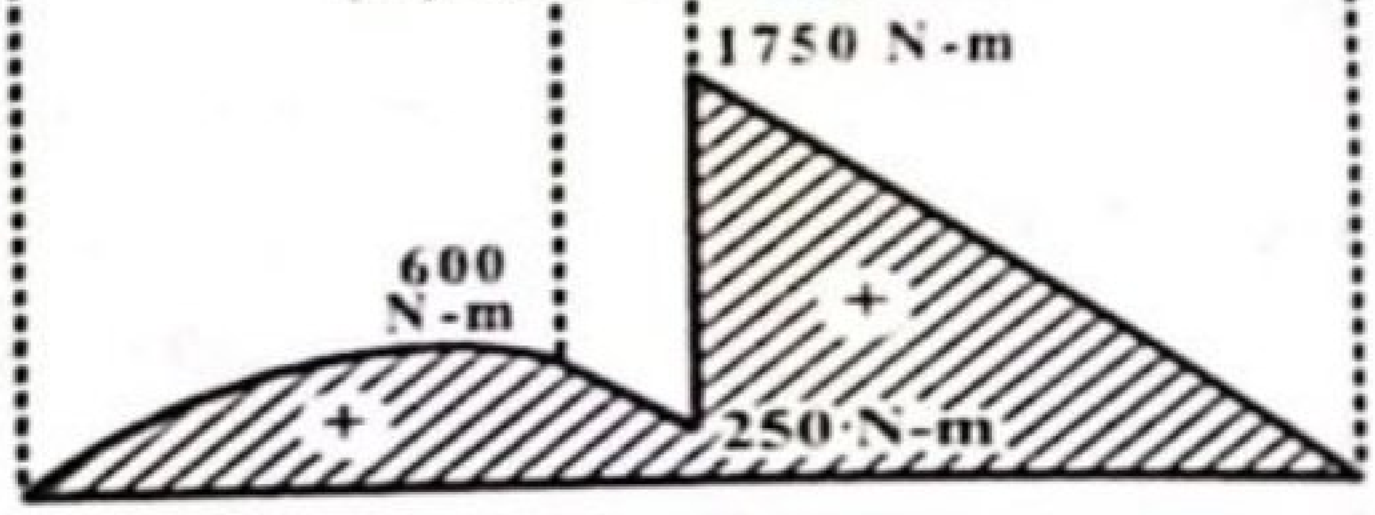
$$S_X = R_A - 1000\,x = 1300 - 1000\,x$$



(a) Given Beam



(b) S.F. Diagram



(c) B.M. Diagram

Fig. 5.48

At $x = 2m$, i.e. at B,

$$S_B = 1300 - 1000 \times 2$$
$$= -700 \text{ N}$$

At $x = 0$, i.e. at A,

$$S_A = 1300 - 1000 \times 0$$
$$= 1300 \text{ N}$$

The S.F. diagram for the beam is shown in fig. 5.48 (b).

B.M. Calculations –

B.M. at both supports will be zero, i.e.

$$M_A = M_C = 0$$

B.M. at R.H.S. of D = $700 \times 2.5 = 1750$ N-m

This B.M. will suddenly change due to clockwise couple of 1500 N. The B.M. just left of D will be

$$= 1750 - 1500 = 250 \text{ N}$$

B.M. at B, $\quad M_B = 700 \times 3 - 1500 = 600$ N-m

B.M. at any section X between B and A, at distance x from A will be given by

$$M_x = 1300x - 1000x.\frac{x}{2}$$
$$= 1300x - 500\,x^2$$

At $x = 2m$, i.e. at B,

$$M_B = 1300 \times 2 - 500 \times 2^2$$
$$= 600 \text{ N-m (same as before)}$$

At $x = 0$, i.e at A, $M_A = 0$

The B.M. diagram is shown in fig. 5.48 (c).

Prob.23. A beam AB of 6 m span is loaded as shown in fig. 5.49. Determine the reactions at A and B.

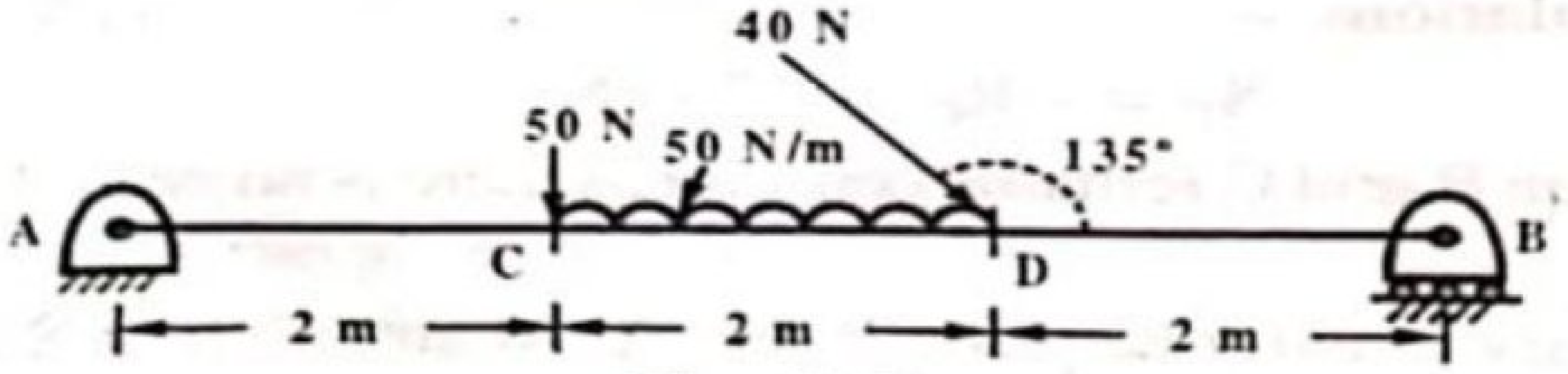


Fig. 5.49

(R.G.P.V., June 2013)

Sol. At roller support B, there will be only vertical reaction, while at fixed support A, there will be both horizontal and vertical reactions. Let R_{AV} and R_B be the vertical reactions at supports A and B respectively and R_{AH} be the horizontal reaction at support A.

Taking moments about A, we get

$$R_B \times 6 = (40 \sin 135^\circ) \times 4 + (50 \times 2 \times 3) + 50 \times 2$$

$$R_B \times 6 = 513.14$$

$$\therefore \quad R_B = \mathbf{85.52\ N} \qquad \textbf{Ans.}$$

and

$$R_{AV} = \text{Total vertical load} - R_B$$

$$= 50 + (50 \times 2) + 40 \sin 135^\circ - 85.52 = 92.76\ N$$

Horizontal reaction at A will be equal to the net horizontal load,

$$R_{AH} = 40 \cos 135^\circ = -28.28\ N = 28.28\ N(\leftarrow)$$

Resultant reaction at support A,

$$R_A = \sqrt{(28.28)^2 + (92.76)^2} = \mathbf{97\ N} \qquad \textbf{Ans.}$$

Prob.24. Draw the shear force and bending moment diagram for beam as shown in fig. 5.50 (a). ***(R.G.P.V., June 2014)***

Sol. The beam is supported on rollers at B, hence roller support at B will not provide any horizontal reaction. The horizontal reaction will be only provided by hinged at A.

Let R_A and R_B be the vertical reactions at A and B respectively.

Taking moments about A.

$$R_B \times 5.5 + 2 - 5 \times 2 \times 2.5 - 10 \sin 60^\circ \times 1.5 = 0$$

$$R_B \times 5.5 = 36$$

$$R_B = \frac{36}{5.5} = 6.54\ \text{kN}$$

$$R_A = \text{Total vertical reaction} - R_B$$

$$= 5 \times 2 + 10 \sin 60^\circ - 6.54 = 12.12\ \text{kN}$$

S.F. Calculations –

S.F. at B, $S_B = -R_B = -6.54$ kN

S.F. between B and D remains constant as there is no vertical load between B and D.

S.F. will vary linearly between D and C. At any section X at a distance x from D, S.F. will be given by

$$S_X = -6.54 + 5 \times x$$

At x = 0, i.e. at D, $S_D = -6.54 + 5 \times 0 = -6.54$ kN

At x = 2, i.e. at C, $S_C = -6.54 + 5 \times 2 = 3.46$ kN

S.F. at C will rise suddenly due to point load i.e.

$$S_C = 3.46 + 10 \sin 60^\circ = 12.12\ \text{kN}$$

S.F. between C and A remains constant as there is no vertical load between C and A.

S.F. diagram is shown in fig. 5.50 (b).

B.M. Calculations –

B.M. at both supports will be zero, i.e.

$$M_A = M_B = 0$$

B.M. at R.H.S. of E

$$= 6.54 \times 1$$

$$= 6.54 \text{ kN-m}$$

This B.M. will suddenly change due to anticlockwise couple of 2 kN-m. The B.M. just left of E

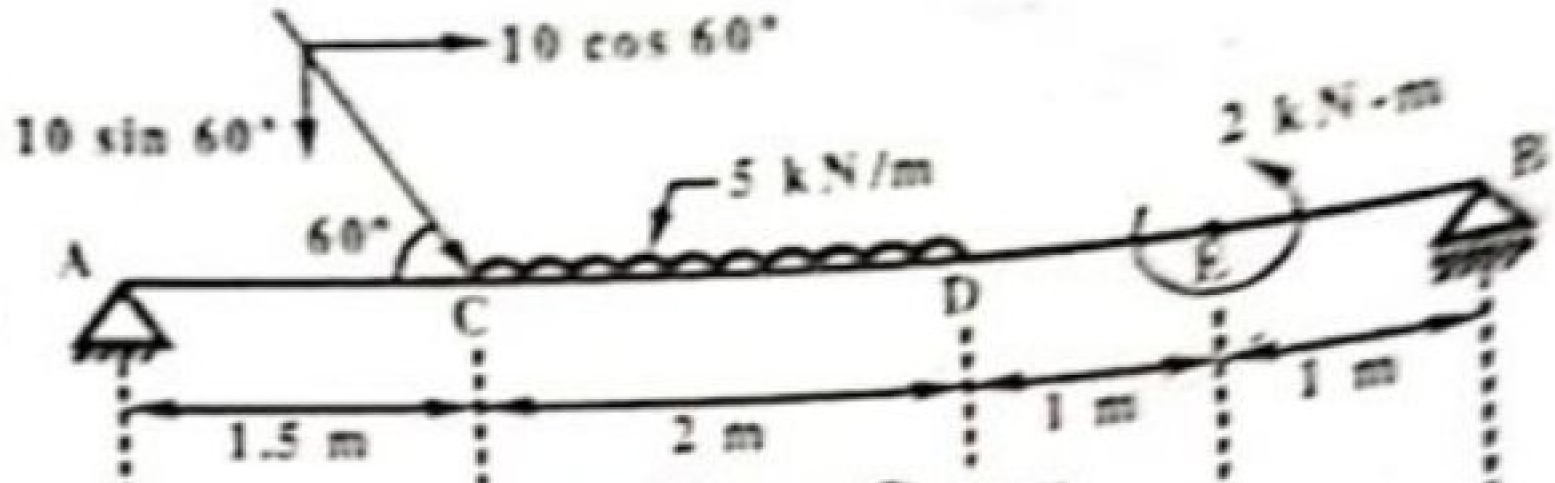
$$= 6.54 + 2$$

$$= 8.54 \text{ kN-m}$$

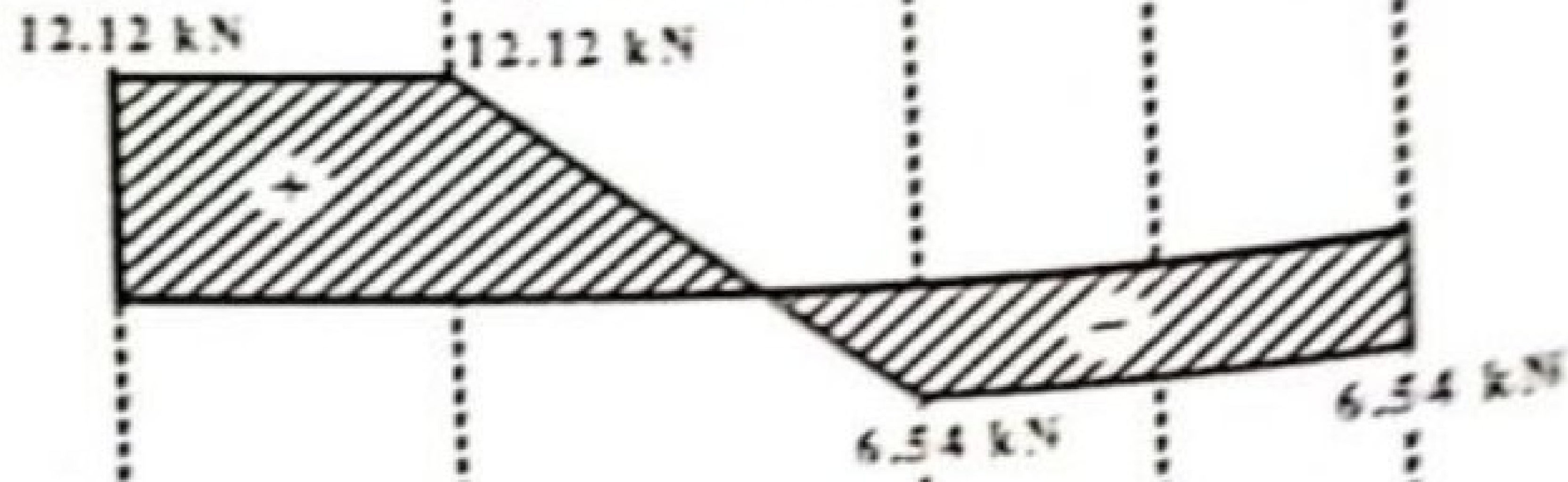
B.M. at D,

$$M_D = 6.54 \times 2 + 2$$

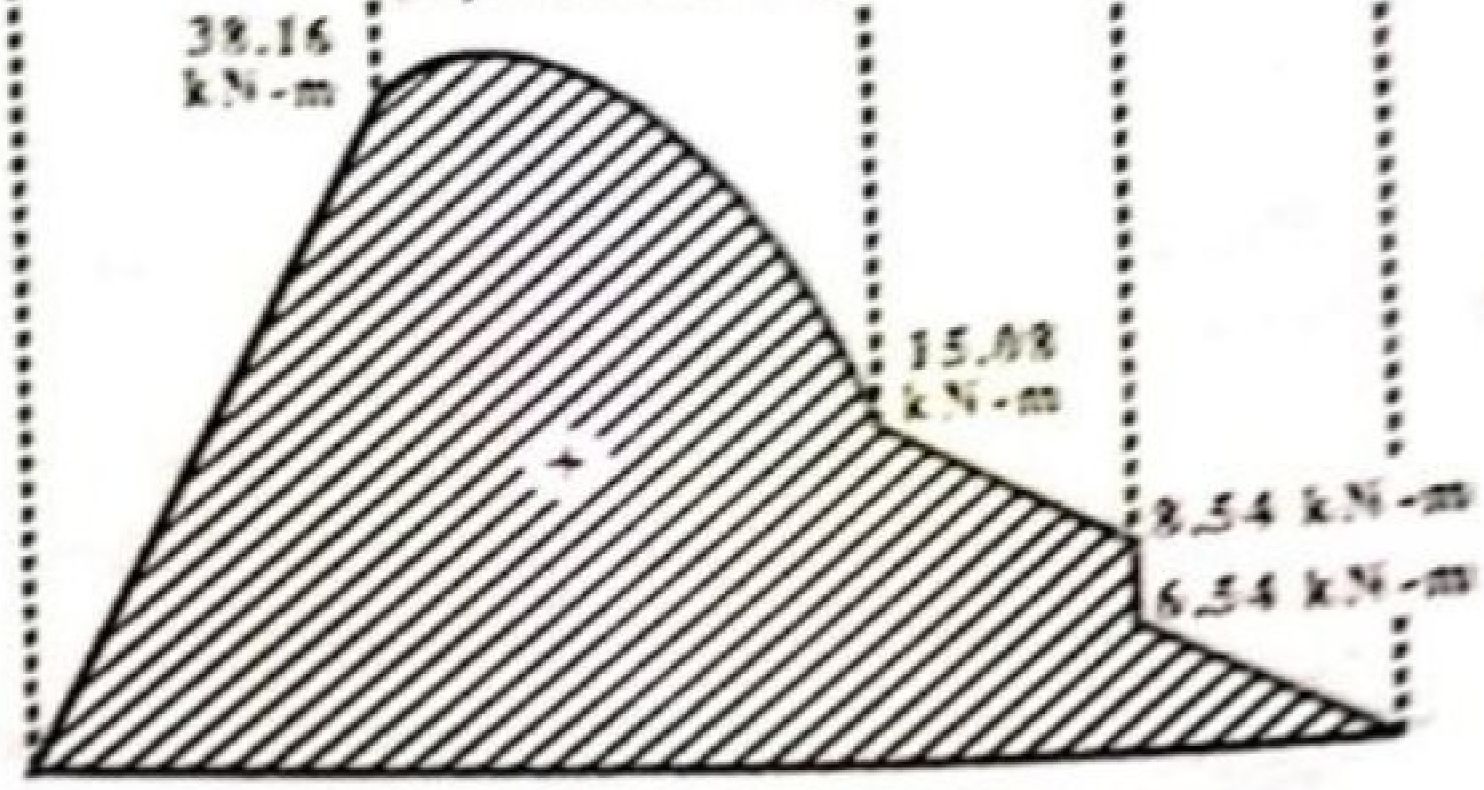
$$= 15.08 \text{ kN-m}$$



(a) Given Beam



(b) S.F. Diagram



(c) B.M. Diagram

Fig. 5.50

B.M. at any section between D and C, at distance x from D, will be given by

$$M_x = 5.x.\frac{x}{2} + 2 + 6.54(x+2)$$

$$= \frac{5x^2}{2} + 2 + 6.54x + 13.08 = \frac{5x^2}{2} + 6.54x + 15.08$$

At $x = 0$, i.e. at D,

$$M_D = 15.08 \text{ kN-m}$$

At $x = 2\text{m}$, i.e. at C,

$$M_C = \frac{5 \times 2^2}{2} + 6.54 \times 2 + 15.08 = 38.16 \text{ kN-m}$$

B.M. diagram is shown in fig. 5.50 (c).

■■■

RGPV

B.E. (First/Second Semester)
EXAMINATION, Dec., 2011
(Common for all Branches)
BASIC CIVIL ENGINEERING AND ENGINEERING MECHANICS [BE-204(GS)]

Note : (i) Attempt *one* question from each Unit.
(ii) All questions carry equal marks.
(iii) Supplement your answers with sketches, wherever required.
(iv) Assume missing data suitably, if any.

Unit-I

1. (a) Mention and describe the various steps involved in production of concrete. (See Unit-I, Page 42, Q.57) 7

(b) Design a staircase for G + 2 storey residential building. The clear height of ground floor and two upper floor is 3.30 m and 3.10 m respectively. Also draw longitudinal section of the designed staircase.

(See Unit-I, Page 98, Prob.1) 7

Or

2. (a) Describe about the various field tests performed to access the quality of bricks. Also discuss about the classification of the bricks. 7

(See Unit-I, Page 15, Q.21)

(b) What is the importance of foundation in a building ? With the help of neat sketches explain about the constructional features of the under-reamed pile foundation. (See Unit-I, Page 66, Q.85) 7

Unit-II

3. (a) The following successive readings were taken with a dumpy level along a chain line at common intervals of 20 m. The R.L. of first station was 120.50 m. The dumpy level was shifted after third, sixth and eighth reading. Calculate R.L. of each station and also find gradient of the line joining first and last station. The readings are : 7

0.945 m, 1.270 m, 1.890 m, 0.655 m, 1.355 m, 1.980 m, 0.730 m, 1.675 m, 0.985 m, 1.805 m, 2.150 m, 3.010 m.

(See Unit-II, Page 174, Prob.28)

(b) Discuss about the merits and demerits of plane table surveying. Also enumerate various accessories used in plane table surveying. 7

(See Unit-II, Page 185, Q.70)

Or

4. (a) Prove mathematically that the errors due to curvature and refractions are removed by reciprocal levelling. Derive suitable formula for finding

true difference of elevation between two points using reciprocal levelling. (See Unit-II, Page 156, Q.45) 7

(b) Compare prismatic and surveyor's compass. (See Unit-II, Page 125, Q.23) 7

Unit-III

5. (a) Define and describe remote sensing. Explain its applications in various fields. (See Unit-III, Page 225, Q.25) 7

(b) What do you mean by contours ? Describe about the characteristics of the contours. (See Unit-III, Page 297, Q.1) 7

Or

6. (a) A series of offsets were taken from a chain line to a curved boundary line at intervals of 15 m in the following order :

0.00, 2.65, 3.80, 4.65 3.60, 4.95, 5.85 metre

Compute the area between the chain line and the curved boundary and the end offset by : 7

(i) Simpson's rule (ii) Trapezoidal rule

(See Unit-III, Page 220, Prob.3)

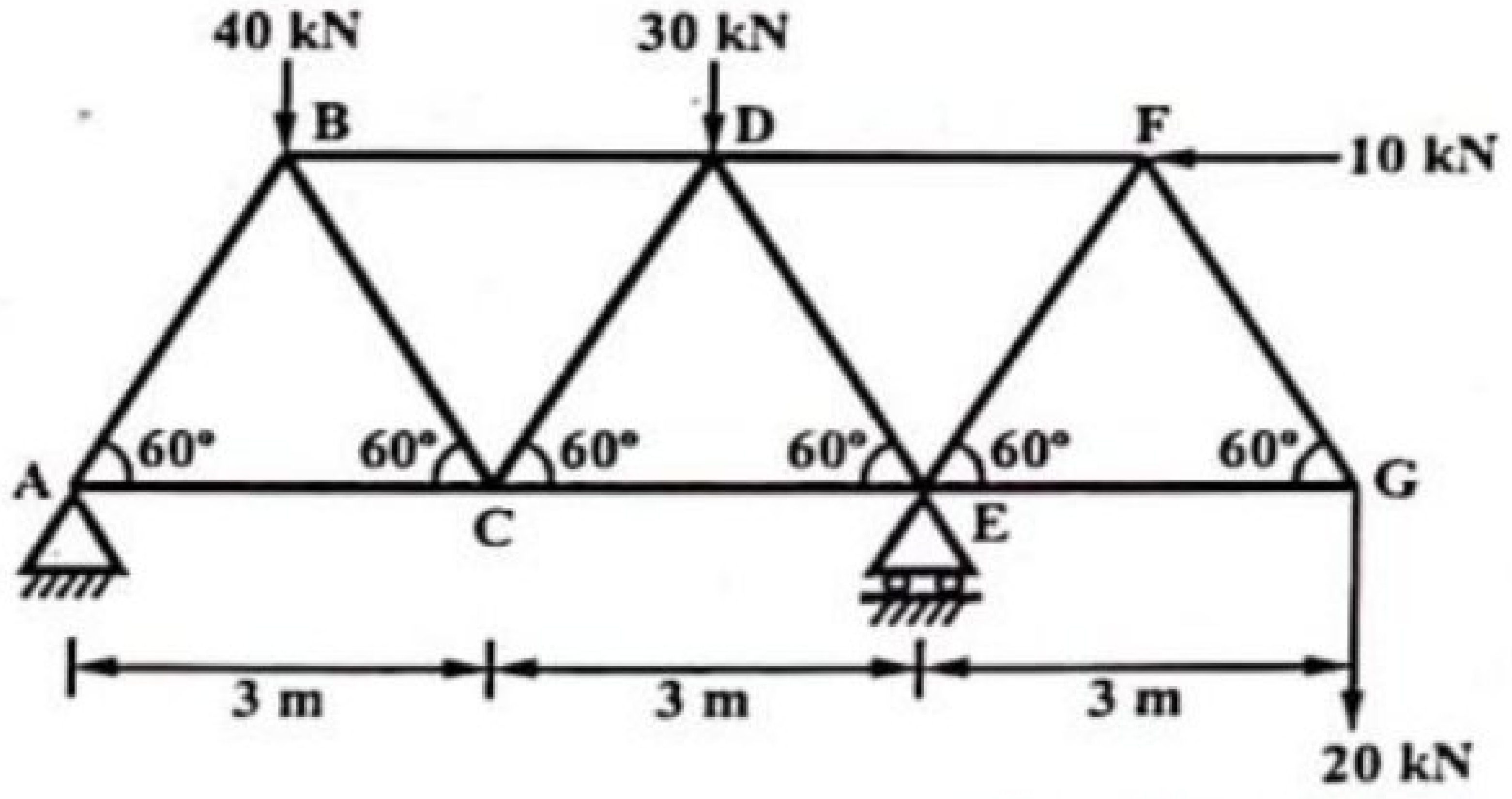
(b) Explain the following terms :

Profile levelling, Check lines, Tie line, GTS Benchmark, Well conditioned triangle, Local attraction error. 7

(See Unit-II, Page 196, Q.81)

Unit-IV

7. (a) Analyse the truss shown below. All members are of 3.0 m length. 7



(See Unit-IV, Page 275, Prob.15)

(b) A 3000 N block is placed on an inclined plane as shown in figure. Find the maximum value of W for equilibrium if tipping does not occur. Assume coefficient of friction as 0.2. ** 7

**Now, according to new revised syllabus of R.G.P.V., it is not included in syllabus

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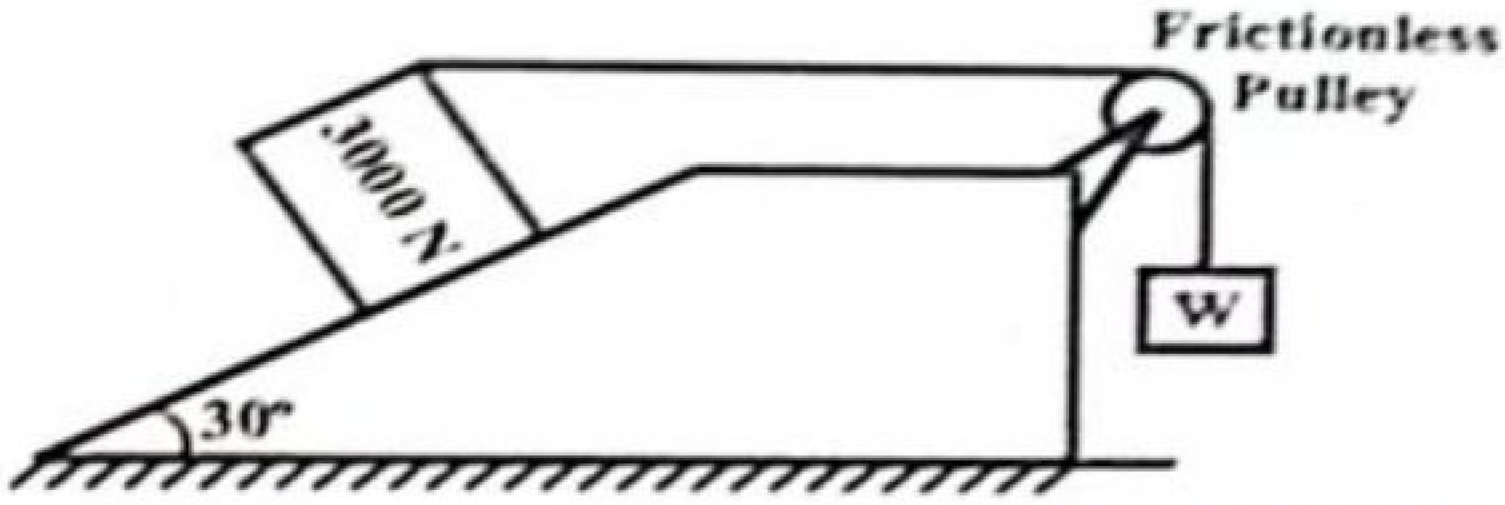
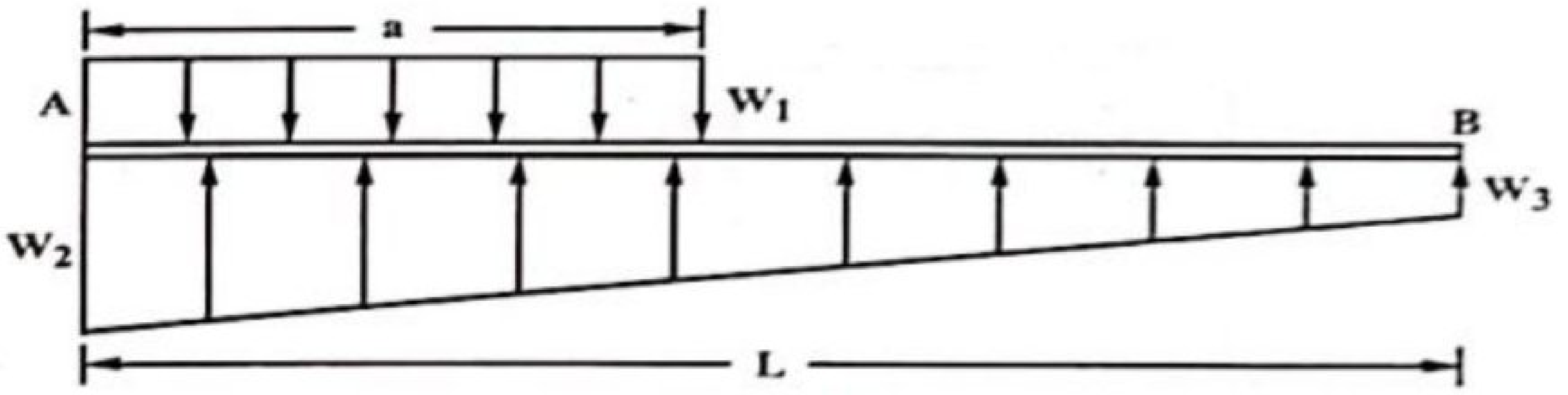


(See Unit-IV, Page 293, Prob.19)

Or

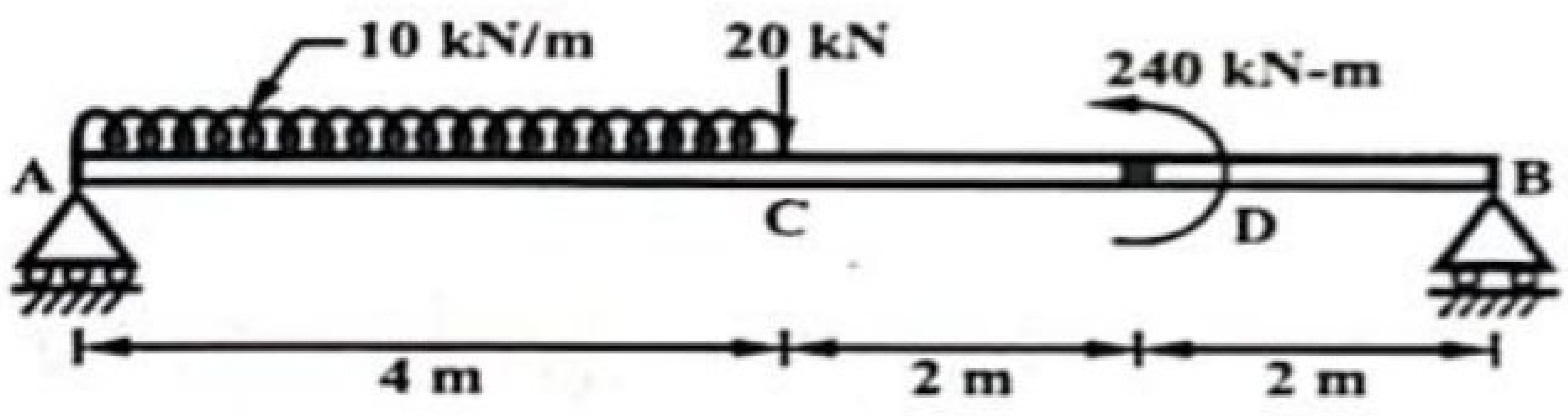
8. (a) What do you mean by perfect, deficient and redundant frames ? What are the assumptions made in analysis of perfect frames ? 7
(See Unit-IV, Page 264, Q.42)

(b) A beam AB supports a U.D.L. of intensity W_1 and rests on soil which exerts a uniformly varying upward reaction as shown in figure. Determine W_2 and W_3 corresponding to equilibrium. Note that soil can exert only an upward reaction at any point on the beam. Hence state for what range of values of a/L the results obtained are valid. 7



Unit-V

9. (a) Draw the SF and BM diagram for beam shown in below mentioned figure. Find out the position and magnitude of maximum moment. 7

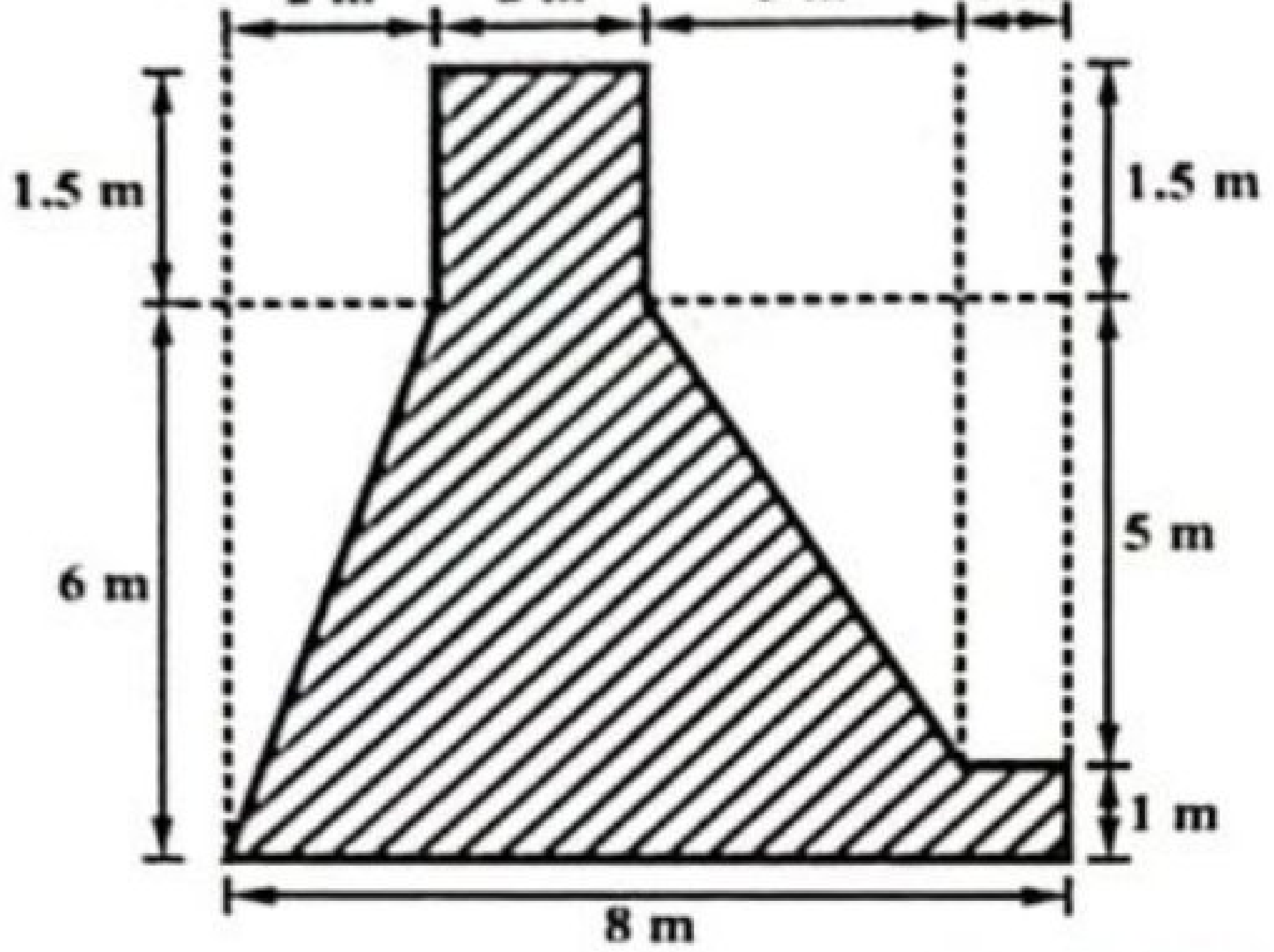


(See Unit-V, Page 347, Prob.21)

(b) Find out the moment of inertia of a circular lamina about its diametral axis using first principle. (See Unit-V, Page 312, Q.18) 7

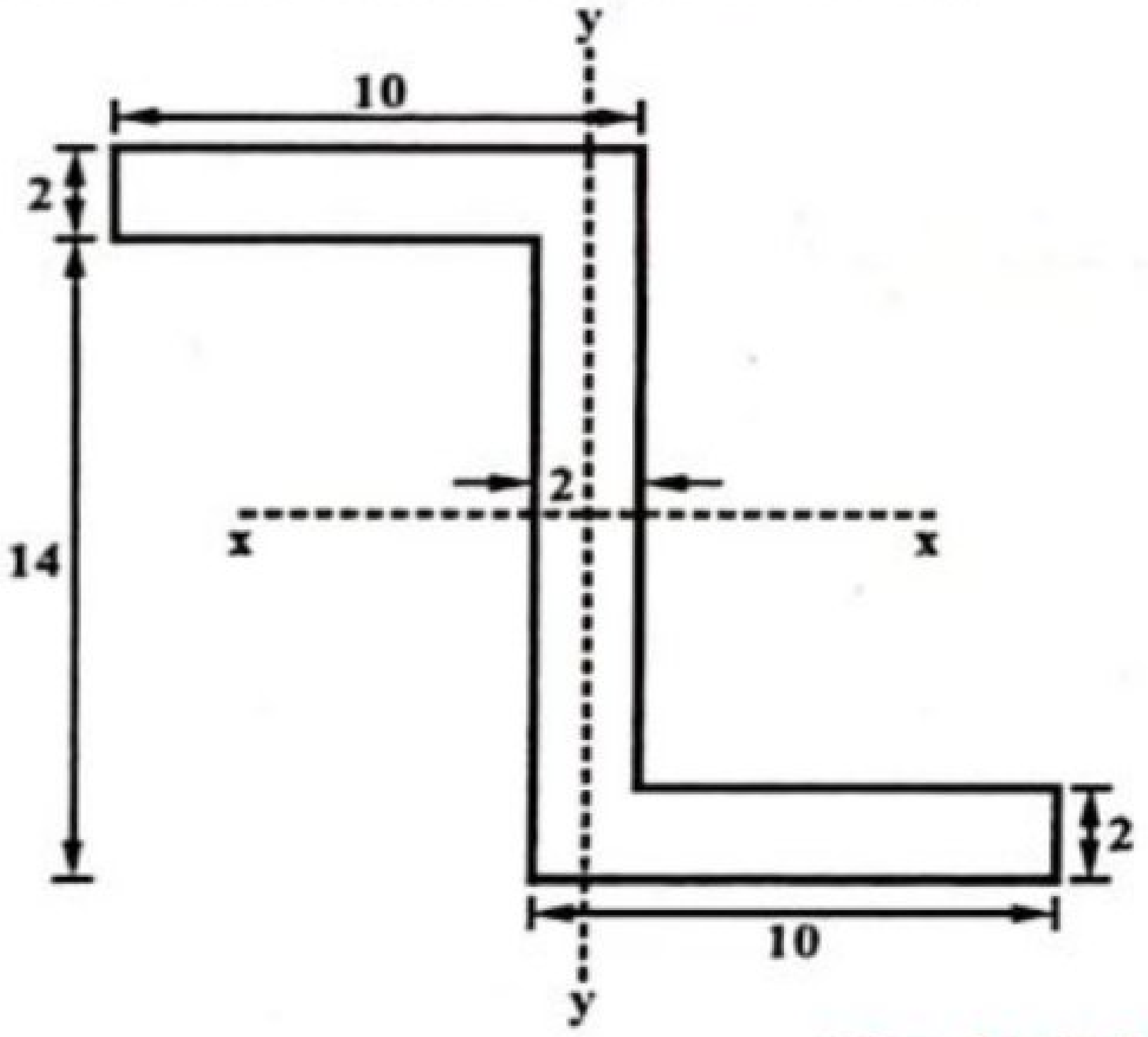
Or

10.(a) Determine the centroid of the section of the concrete dam shown in figure. 7



(See Unit-V, Page 304, Prob.3)

(b) Determine moment of inertia of the Z-section about the centroidal axis X-X and Y-Y. All dimensions are in cm. 7



(See Unit-V, Page 321, Prob.9)

RGPV

B.E. (First/Second Semester)
EXAMINATION, June, 2012
(Grading System)
(Common for all Braches)
BASIC CIVIL ENGINEERING
& ENGINEERING MECHANICS [BE-204 (GS)]

Note : (i) Attempt one question from each unit.

(ii) All questions carry equal marks

(iii) Supplement your answer with sketches, wherever required

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(iv) Assume missing data, if any

Unit-I

1. (a) Draw a neat labelled diagram of R.C.C. footing for a circular column of 300 mm dia. (See Unit-I, Page 67, Q.87) 7

   (b) Explain about the various consideratons for selecting location of staircase. (See Unit-I, Page 93, Q.113) 7

Or

2. (a) How the quality of cement can be accessed ? Explain in brief regarding the laboratory and field tests performed on the cement. 7 (See Unit-I, Page 21, Q.29)

   (b) What is the importance of initial and final setting time of cement ? How these times can be suitably controlled ? (See Unit-I, Page 24, Q.31) 7

Unit-II

3. (a) What do you mean by reciprocal levelling ? Prove that using reciprocal levelling the errors due to curvature/collimation can be eliminated. 7 (See Unit-II, Page 156, Q.45)

   (b) A survey line PQR crosses a river. The points PQ are on one side and the point R is on other side of the river. The point Q is close to the bank of river. Perpendicular QS 60 metre long is set out at Q. If the bearings of PS and SR are 62° & 332° and the distance PQ is 35m. Find the distance PR. (See Unit-II, Page 139, Prob.4) 7

Or

4. (a) Following staff readings (in metre) were observed successively with level, the instrument having been shifted after the 2nd, 4th and 8th readings.

   0.875, 1.235, 2.310, 1.385, 2.930, 3.125, 4.125, 0.120, 1.875, 2.030, 3.765.

   The first reading was taken with the staff held upon a benchmark of elevation 142.870m. Enter the readings in level book page and reduce levels. Apply usual checks also. (See Unit-II, Page 170, Prob.22) 7

   (b) Explain step by step procedure of method of traversing of plane-table surveying. Also discuss about the checks applied. 7 (See Unit-II, Page 189, Q.74)

Unit-III

5. (a) Explain in details how the contour map can be used for engineering purposes. (See Unit-III, Page 203, Q.13) 7

   (b) Following perpendicular offsets were taken from a chain-line to an irregular boundary.

Chainage (m)	0	10	25	42	50	75
Offset (m)	12.5	26.2	28.7	32.6	21.9	29.0

Calculate area between the chain line, the boundary and the end offsets using trapezoidal method. **(See Unit-III, Page 218, Prob.1)** 7

Or

6. **(a)** What do you understand by remote sensing ? What are its various applications ? **(See Unit-III, Page 225, Q.25)** 7

(b) Explain step by step procedure, how the capacity of reservoir can be determined using contour maps. **(See Unit-III, Page 202, Q.12)** 7

Unit-IV

7. **(a)** A roller of radius r = 300 mm and weight 2000N is to be pulled over a curb of height 150 mm by a horizontal force P applied to the end of string tightly wound around the circumference of the roller. Find the magnitude of P required to start the roller move over the curb. What is the least pull P through the centre of the wheel to just turn the roller over the curb ? (Fig. 1) **(See Unit-IV, Page 253, Prob.6)** 7

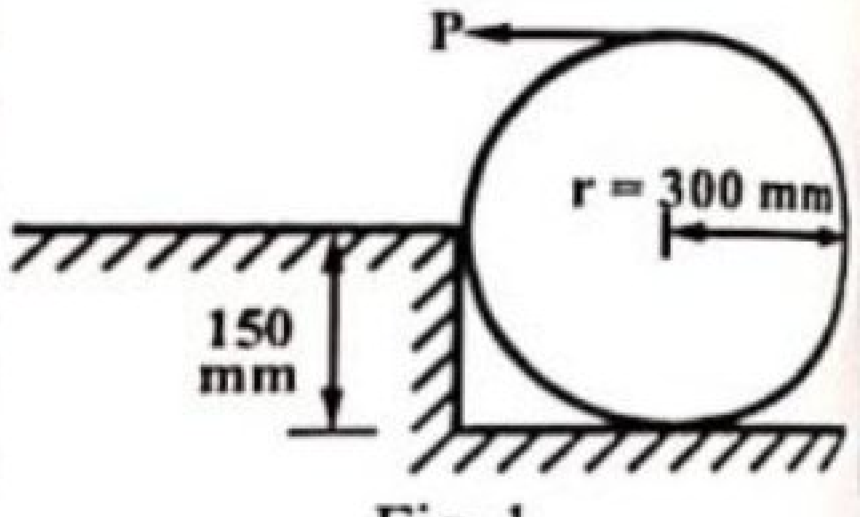

Fig. 1

(b) State and prove Varignon's theorem. **(See Unit-IV, Page 238, Q.20)** 7

Or

8. **(a)** Find the forces in the all members of the truss as shown in fig. 2. 7

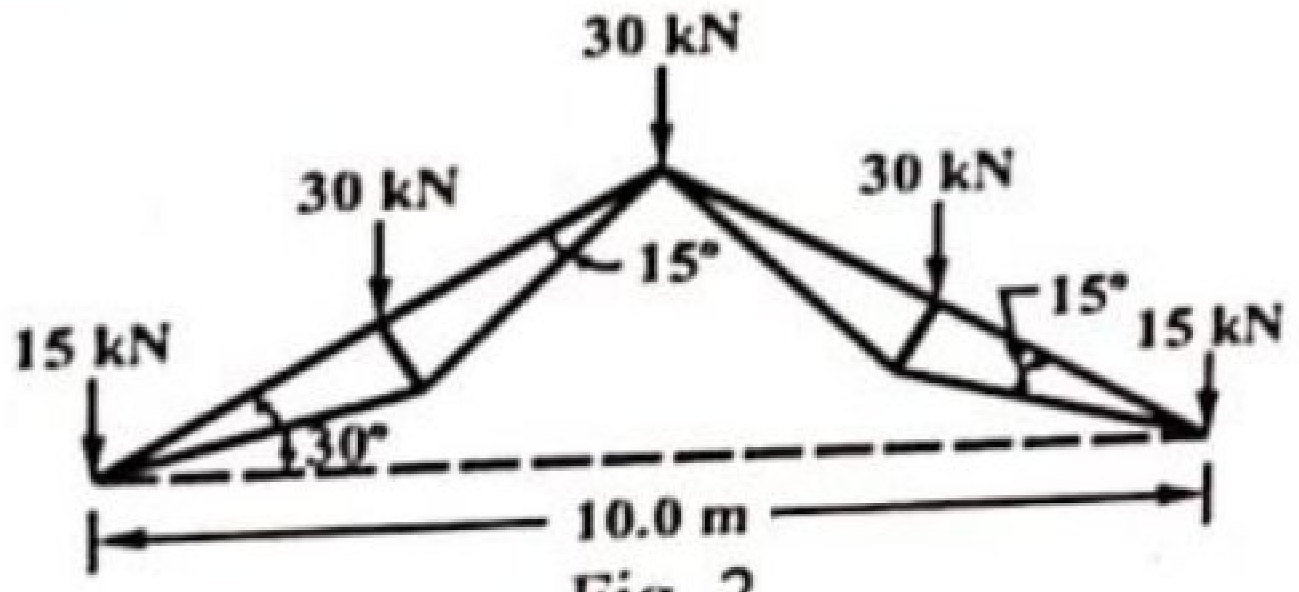

Fig. 2

(b) A 4m ladder weighing 200N is placed against a vertical wall as shown in fig. 3. As a man weighing 800N, reaches a point 2.7m from A, the ladder is about to slip. Assuming that the coefficient of friction between the ladder and the wall is 0.2, determine coefficient of friction between the ladder and the floor.

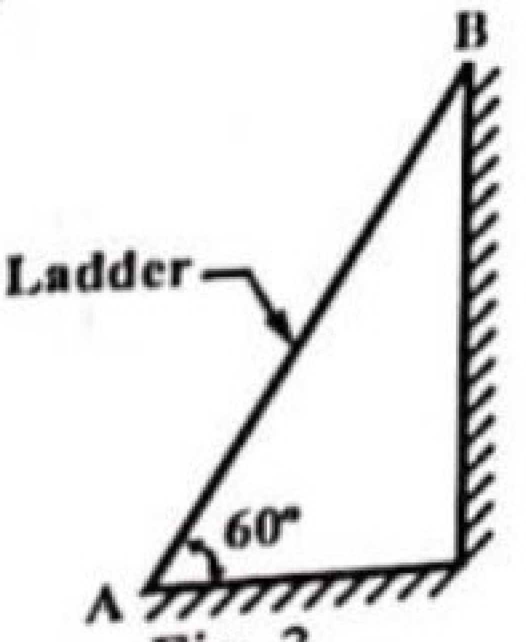

Fig. 3

(See Unit-IV, Page 295, Q.21)

Unit-V

9. **(a)** Determine moment of inertia of the circle about its diametral axis using first principle. **(See Unit-V, Page 312, Q.18)** 7

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(b) Determine the centroid of the area shown in fig. 4 with respect to axes shown in fig. 7

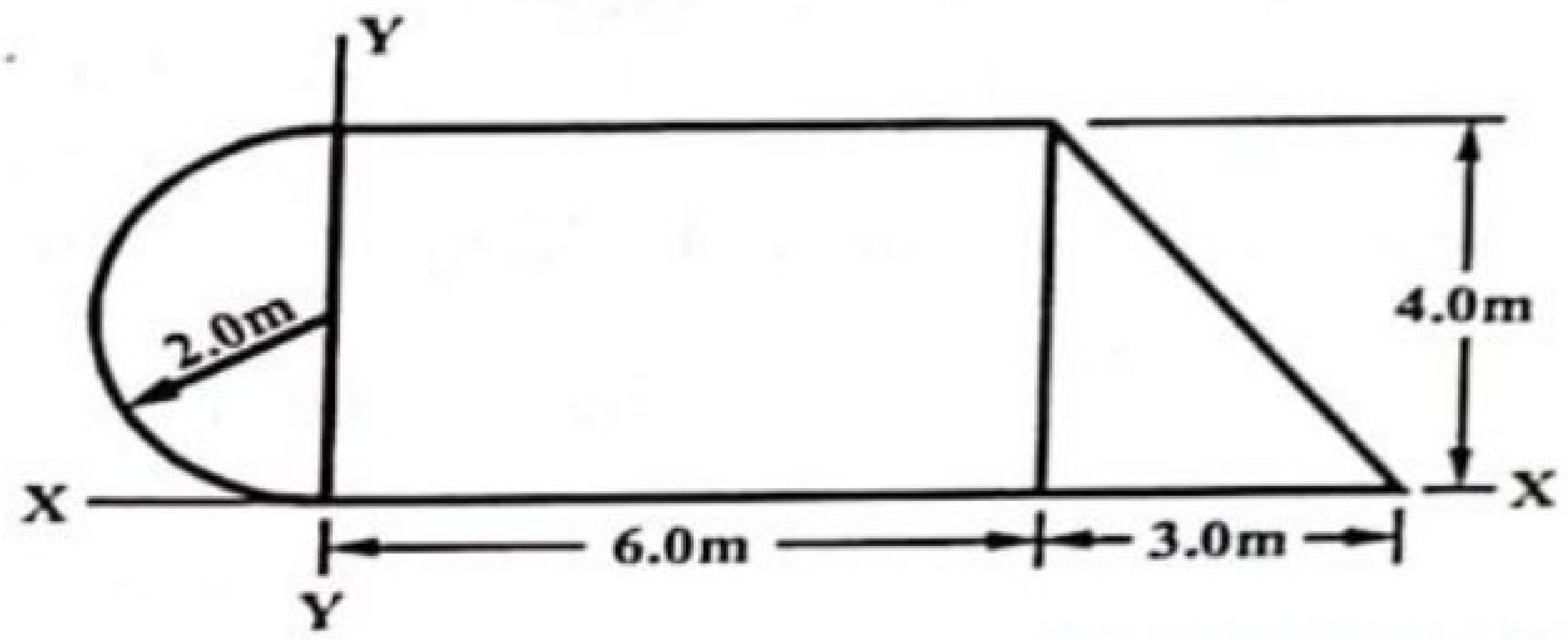


Fig. 4 **(See Unit-V, Page 306, Prob.4)**

Or

10.(a) Determine the reactions at A, B and D of the system shown in fig. 5. Neglect self weight. 7

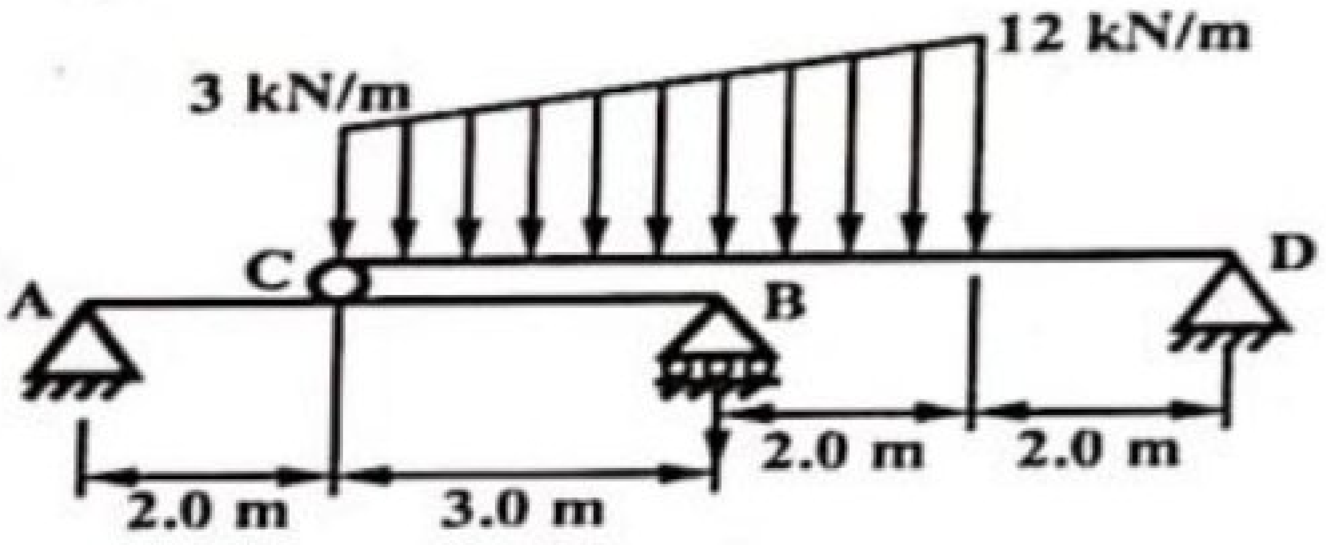


Fig. 5

(b) Draw S.F. and B.M. Diagram for the beam shown above in fig. 6. 7

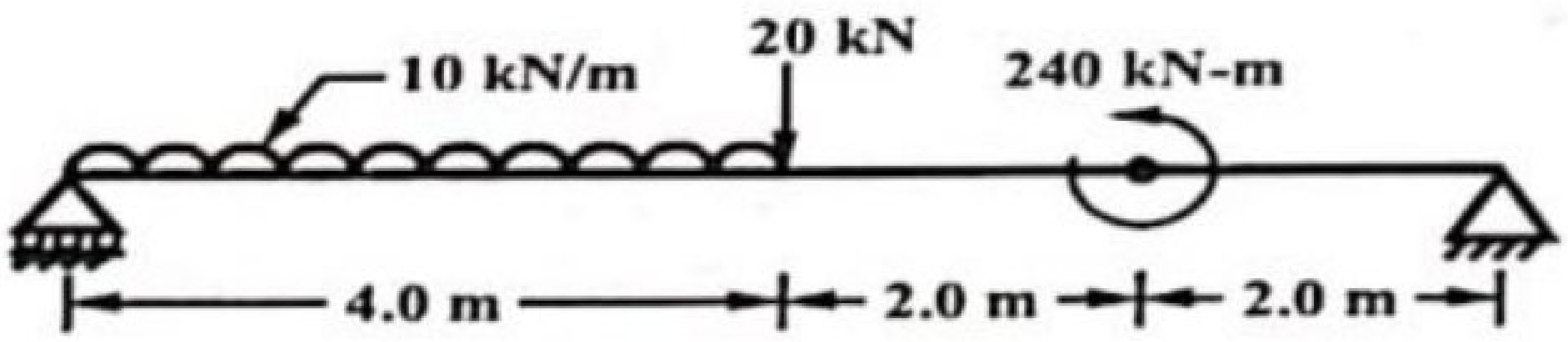


Fig. 6 **(See Unit-V, Page 347, Prob.21)**

B.E. (First/Second Semester)
EXAMINATION, Dec., 2012
(Grading System)
(Common for all Braches)
BASIC CIVIL ENGINEERING
& ENGINEERING MECHANICS [BE-204 (GS)]

Note : Attempt any five questions. Internal choice is given in each question. Assume suitable data if required.

1. (a) What is concrete ? Describe the process of preparation of concrete.

(See Unit-I, Page 44, Q.59)

(b) What are the various field tests applied on bricks to judge the quality of bricks ? **(See Unit-I, Page 14, Q.19)**

Or

2. **(a)** Draw the neat sketches of the following –

(i) King post roof truss (ii) Open newel stairs.

(See Unit-I, Page 97, Q.117)

(b) Explain the various elements of building construction.

(See Unit-I, Page 53, Q.73)

3. **(a)** What are the various methods of plane table surveying ? Explain any two in detail. **(See Unit-II, Page 187, Q.72)**

(b) Explain the EDM method in detail. **(See Unit-II, Page 193, Q.78)**

Or

4. **(a)** Describe any two methods of measuring horizontal angle with theodolite. **(See Unit-II, Page 182, Q.66)**

(b) The following consecutive readings were taken with the help of dumpy level

1.905, 2.655, 3.905, 4.025, 1.965, 1.705, 1.595, 1.265, 2.545, 2.005, 3.145.

The instrument was shifted after the fourth and seventh readings. The first reading was taken on the staff held on B.M. of R.L. 100.000 m. Rule out a page of level field book, enter the above readings there on. Calculate the R.Ls. of the points and apply the arithmetic check.

(See Unit-II, Page 170, Prob.21)

5. **(a)** Define 'contour'. What are the various characteristics of contour ?

(See Unit-III, Page 197, Q.1)

(b) The following perpendicular offsets were taken at 20 m intervals from a base line to an irregular boundary line.

5.9, 12.4, 16.5, 15.3, 18.4, 20.9, 24.9, 21.8, and 19.2 metres. Calculate the area enclosed between the base line, the irregular boundary line and the first and last offsets by –

(i) Trapezoidal Rule (ii) Simpson's Rule **(See Unit-III, Page 222, Prob.6)**

Or

6. **(a)** Explain the term 'Remote sensing' in detail. What are the various applications of remote sensing. **(See Unit-III, Page 225, Q.25)**

(b) Explain the following in detail

(i) Survey stations. **(See Unit-III, Page 218, Q.22)**

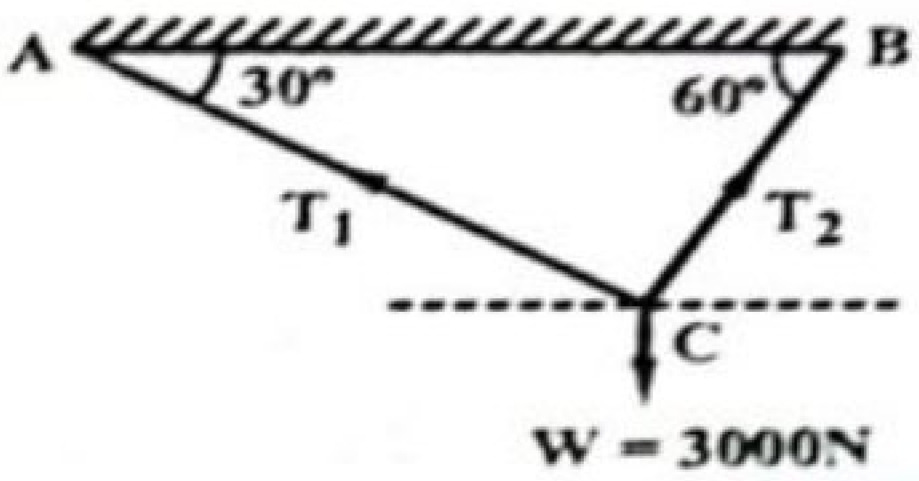
(ii) Methods for measuring the area and volume.

(See Unit-III, Page 217, Q.19)

7. **(a)** Define various types of forces with the help of sketches.

(See Unit-IV, Page 230, Q.5)

(b) A weight of 3000 N is supported by two chains AC and BC as shown in fig. below. Determine the tension in each chain.



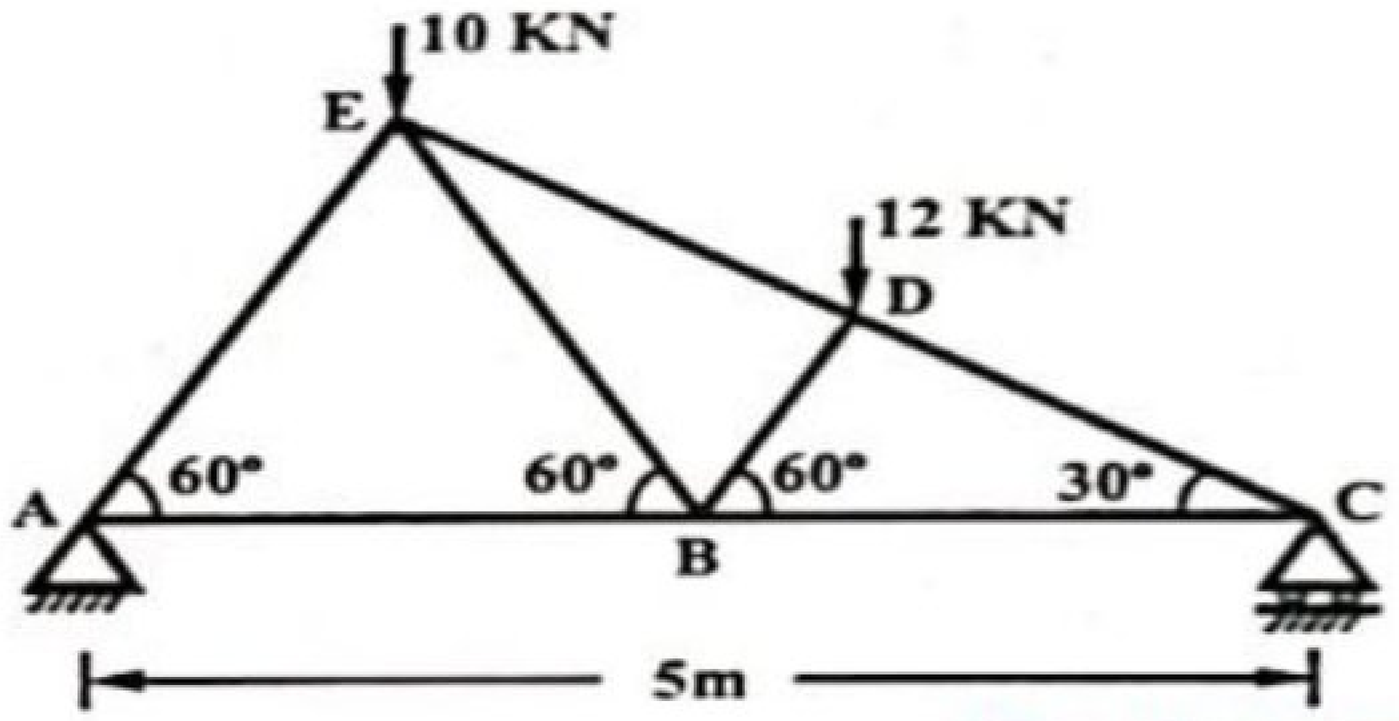
(See Unit-IV, Page 255, Prob.7)

Or

8. **(a)** State and explain the Triangle law and polygon law of forces.

(See Unit-IV, Page 236, Q.15)

(b) Determine the forces in all the members of the truss loaded and supported as shown in fig. below.

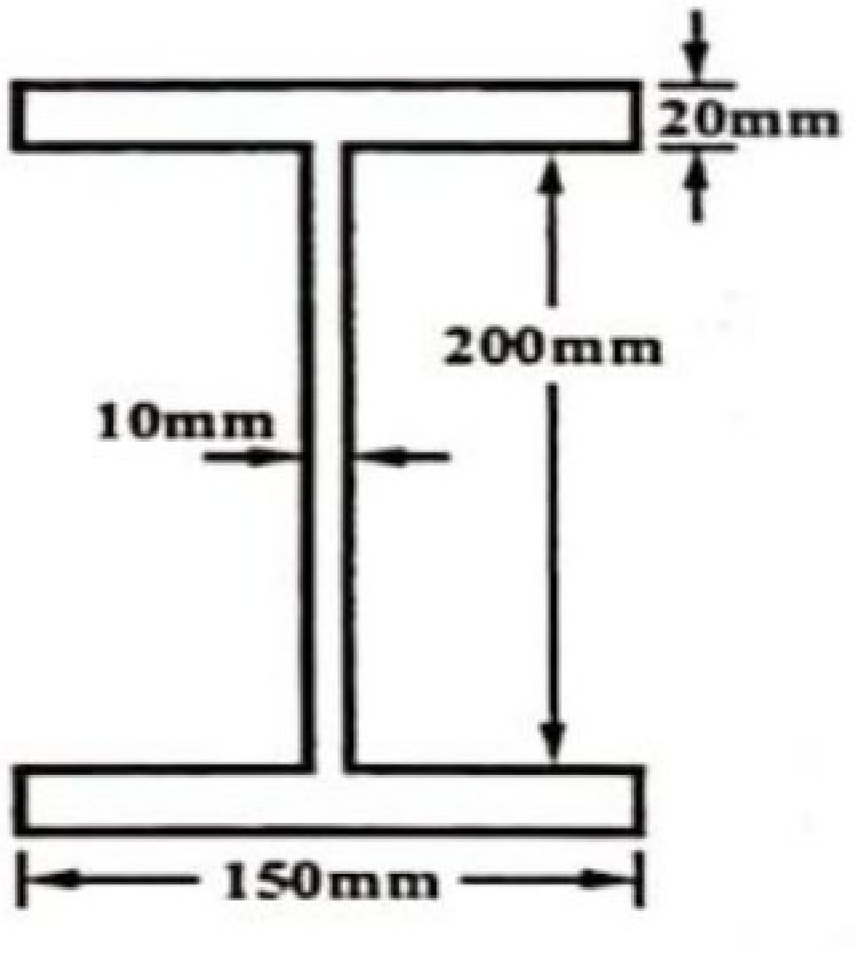


(See Unit-IV, Page 267, Prob.11)

9. **(a)** State parallel and perpendicular axis theorems. Explain any one in detail.

(See Unit-V, Page 310, Q.14)

(b) Find the moment of inertia of a rolled steel joist girder of symmetrical I section shown in fig. below.

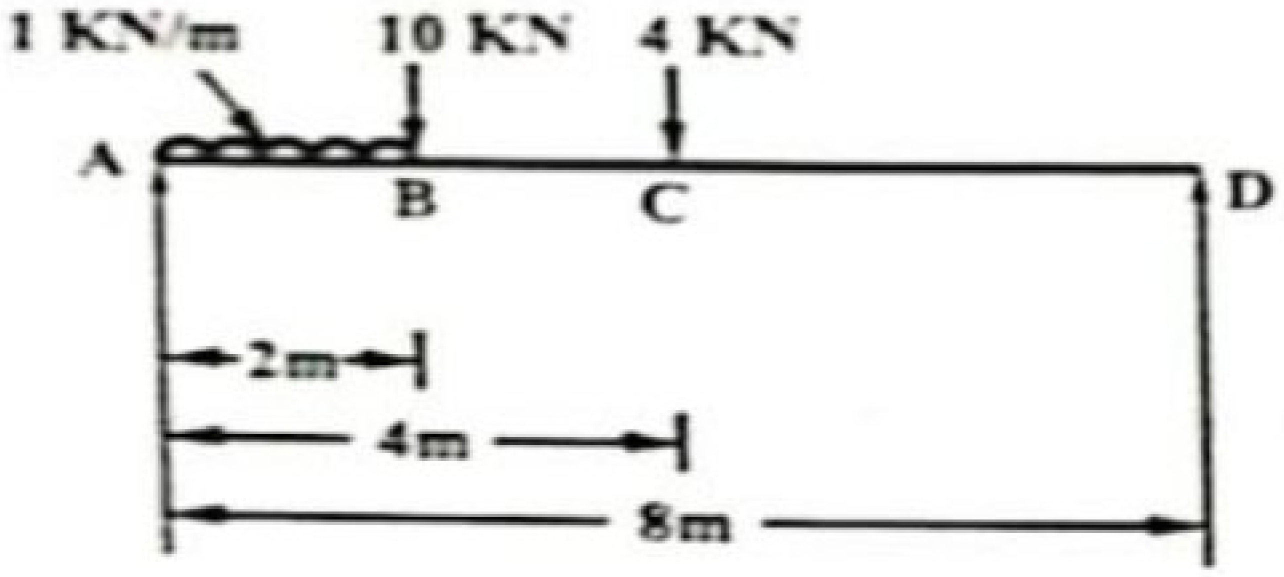


(See Unit-V, Page 324, Prob.10)

Or

10. **(a)** Define various types of beams and loadings with the help of neat sketches. (See Unit-V, Page 336, Q.31)

(b) Draw the shear force and bending moment diagram for the beam loaded and supported as shown below.



(See Unit-V, Page 342, Prob.17)

RGPV

B.E. (First/Second Semester)
EXAMINATION, June, 2013
(Common for all Braches)
BASIC CIVIL ENGINEERING
& ENGINEERING MECHANICS (BE-204)

Note : Attempt any five questions. Internal choice is given with each question. Assume suitable data if any is missing or misprint.

1. (a) What do you understand by lab test and field Test ? Describe various field tests applied on bricks to judge the quality of bricks. 7
(See Unit-I, Page 15, Q.20)

(b) Differentiate between the following – 7
(i) Plastering and pointing (See Unit-I, Page 74, Q.94)
(ii) Concrete and mortar. (See Unit-I, Page 47, Q.63)

Or

2. (a) Define the term workability. Discuss various factors which affect workability of concrete. (See Unit-I, Page 37, Q.50) 7

(b) Differentiate between following – 7
(i) Footing and Foundation (See Unit-I, Page 58, Q.80)
(ii) Bleeding and segregation. (See Unit-I, Page 46, Q.62)

3. (a) State various methods of plane table surveying. Explain any one method in detail. (See Unit-II, Page 187, Q.73) 7

(b) A 20 m chain was used to measure a distance of 8000 m. After measuring 3500 m. It was found that the chain was 3 cm too long which was correct in the beginning of the work. Again it was found at the end of the work that chain was 6 cm too long. Calculate the correct distance measured. (See Unit-II, Page 138, Prob.3) 7

Or

4. (a) Explain the following – 6
(i) EDM method (See Unit-II, Page 193, Q.78)
(ii) Reciprocal levelling. (See Unit-II, Page 156, Q.45)

(b) The following consecutive readings were taken with a level and a 4.0 m staff on a continuously sloping ground at common interval of 30 m. 0.780, 1.535, 1.955, 2.430, 2.985, 3.480, 1.155, 1.960, 2.365, 3.640, 0.935, 1.045, 1.630 and 2.545. The reduced level of the first point 'A' was 180.750 m. Rule out a page of a level field book and enter the above readings. Calculate the reduced levels of all the points and apply proper check for calculation. 8

(See Unit-II, Page 171, Prob.24)

5. (a) What are the various direct and indirect methods of contouring ? Explain any one indirect method of contouring. 7

(See Unit-III, Page 206, Q.14)

(b) A railway embankment is 12 m wide. The ground is level in the direction transverse to the centre line. Calculate the volume contained in a 100 m length by trapezoidal and prismoidal rule, if the side slope is 1:5:1. The centre height at 20 m interval are 3.7 m, 2.6 m, 4.0 m, 3.4 m, 2.8 m, 3.0 m, 2.2 m. **(See Unit-III, Page 222, Prob.7)**

Or

6. (a) Define the following terms related to contour 6

(i) Contour
(ii) Horizontal equivalent
(iii) Cliff
(iv) Contour interval
(v) Grade contour
(vi) Ghat tracer.

(See Unit-III, Page 201, Q.7)

(b) What do you understand by survey stations ? Discuss requirements of a good survey station. **(See Unit-III, Page 218, Q.24)** 8

7. (a) Explain the following in detail – 7

(i) Varignon's theorem **(See Unit-IV, Page 238, Q.20)**
(ii) Conditions of equilibrium. **(See Unit-IV, Page 250, Q.35)**

(b) A machine component of length 2.5 m and height 1 m is carried upstairs by two men, who hold it by the front and back edges of its lower face. If the machine component is inclined at 30° to the horizontal and weights 100 N, find how much of the weight each man shares. 7

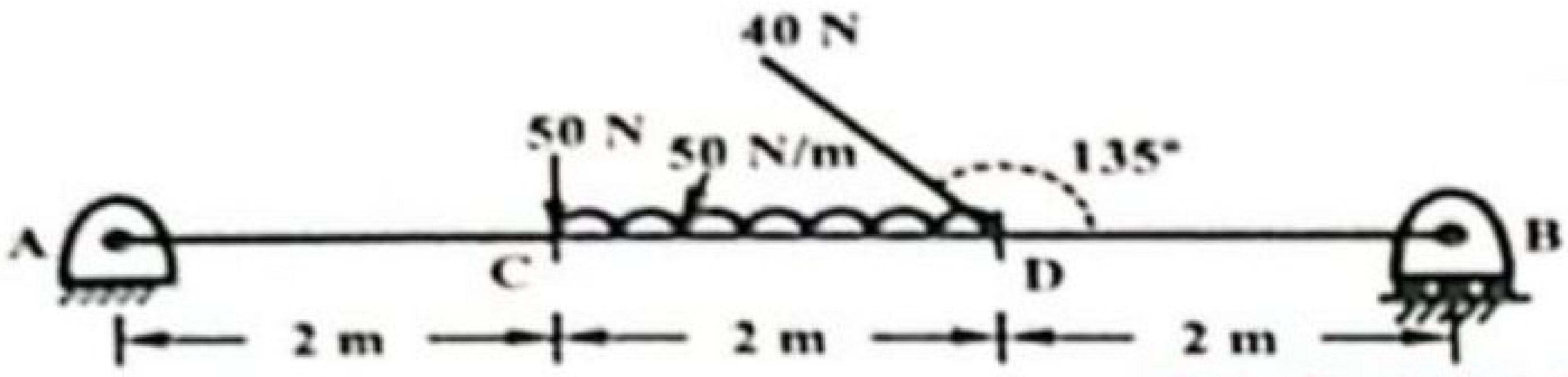
(See Unit-IV, Page 243, Prob.2)

Or

8. (a) What is couple ? Differentiate between moment and couple. 7

(See Unit-IV, Page 240, Q.23)

(b) A beam AB of 6 m span is loaded as shown in fig. below. Determine the reactions at A & B. 7

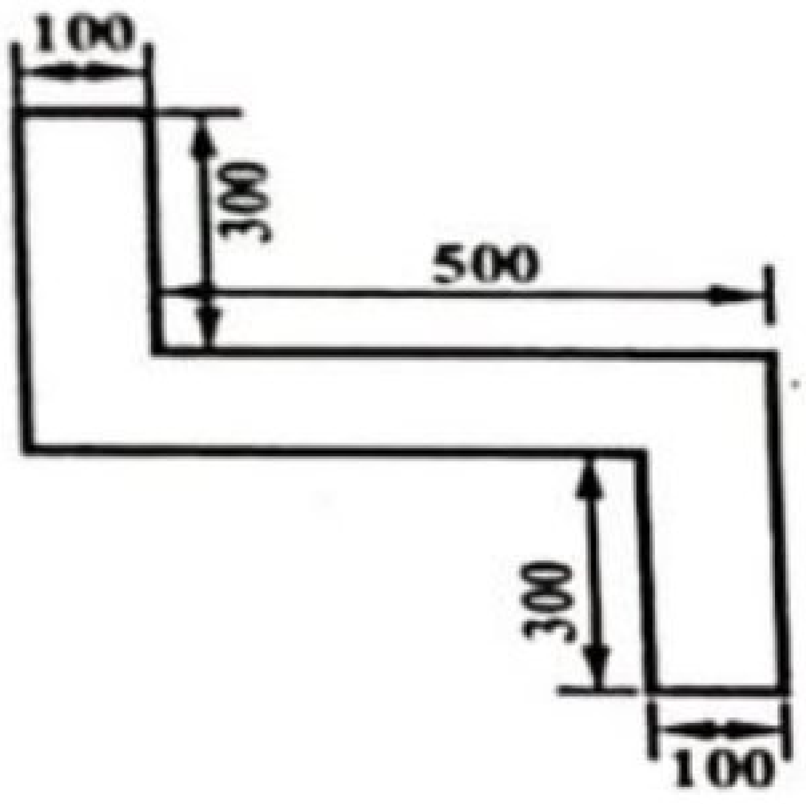


(See Unit-V, Page 350, Q.23)

9. (a) State and prove the theorem of parallel axis. 7

(See Unit-V, Page 308, Q.11)

(b) Determine the principle moment of inertia of the section shown in fig. below about its centroid. All dimensions are in mm. 7

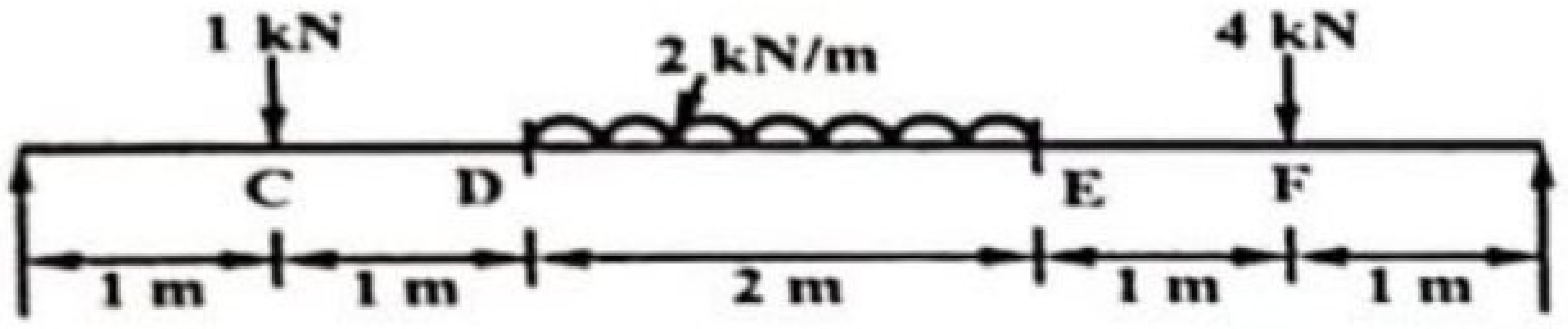


(See Unit-V, Page 331, Prob.13)

Or

10.(a) Show with the help of neat sketches the various types of beams and loadings. (See Unit-V, Page 336, Q.31) 6

(b) Draw the shear force and bending moment diagram for the beam loaded as shown in fig. below. Clearly mark the position of maximum bending moment and determine its value. 8



(See Unit-V, Page 343, Q.18)

RGPV

B.E. (First/Second Semester)
EXAMINATION, Dec., 2013
(Common for all Braches)
BASIC CIVIL ENGINEERING & ENGINEERING MECHANICS
(BE-204)

Note : (i) Attempt all questions.
(ii) Internal choice is given with each question.

(iii) All questions carry equal marks.

(iv) Any data missing but essential may be assumed suitably and should stated.

1. (a) What is concrete and how is it made ? Also mention factors affecting strength of concrete. (See Unit-I, Page 44, Q.58)

(b) Describe briefly the tests to which bricks may be put before using them for engineering purposes. (See Unit-I, Page 14, Q.19)

Or

2. (a) What are the requirements of a good stair ? Discuss them in detail. (See Unit-I, Page 93, Q.112)

(b) Give a list materials which are commonly used as floorings and give a brief description of each material. (See Unit-I, Page 75, Q.96)

3. The following consecutive staff readings were taken with a level and 3m leveling staff on a continuously slopping ground at a common interval of 20m:0.605, 1.235, 1.860, 2.575, 0.240, 0.915, 1.935, 2.875, 1.825, 2.725. The R.L. of the first point was 192.120. Rule a page of a level field book and enter the above readings. Calculate the reduced levels of the points and also the gradient of the line joining the first and last points.

(See Unit-II, Page 173, Prob.27)

Or

4. (a) What is the basic difference between temporary and permanent adjustments of a theodolite ? (See Unit-II, Page 180, Q.64)

(b) What are the different methods of 'plane tabling' ? Describe the one of them fully with neat sketches. (See Unit-II, Page 187, Q.73)

5. (a) With reference to civil engineering practive explain what is meant by the following :

(i) Trapezoidal and Prismoidal rules. (ii) Prismoidal corrections.

(See Unit-III, Page 217, Q.21)

(b) Describe briefly the remote sensing and its applications.

(See Unit-III, Page 225, Q.25)

Or

6. The following perpendicular offsets in m are measured from a straight line to an irregular boundary at regular intervals of 10m.

$h_1 = 8.25$, $h_2 = 13.85$, $h_3 = 12.25$, $h_4 = 10.85$, $h_5 = 12.25$, $h_6 = 13.60$, $h_7 = 15.25$, $h_8 = 16.85$, $h_9 = 14.95$, $h_{10} = 17.35$, $h_{11} = 20.05$, $h_{12} = 15.90$, $h_{13} = 12.25$, $h_{14} = 12.00$.

Compute the area included between the straight line, the irregular boundary by

(i) Trapezoidal rule,

(ii) Simpson's one-third rule (a) using h_1 as the first offset, (b) using h_{14} as the last offset. **(See Unit-III, Page 221, Prob.5)**

7. (a) Obtain an expression for minimum force required to move a body on a horizontal plane. **(See Unit-IV, Page 287, Q.56)**

(b) A block of 300N weight is resting on a plane inclined at 30° to the horizontal, the coefficient of friction between the block and the plane is 0.4. A force inclined at an angle of 30° is acting on the block. Find the minimum force to move the block upwards.

(See Unit-IV, Page 294, Q.20)

Or

8. The length of each member of the truss shown in fig. 1 is 4m. Loads of 2kN and 4kN are applied at joints B and C of the truss. Determine the magnitudes and nature of forces in all members of the truss. Both ends are simply supported.

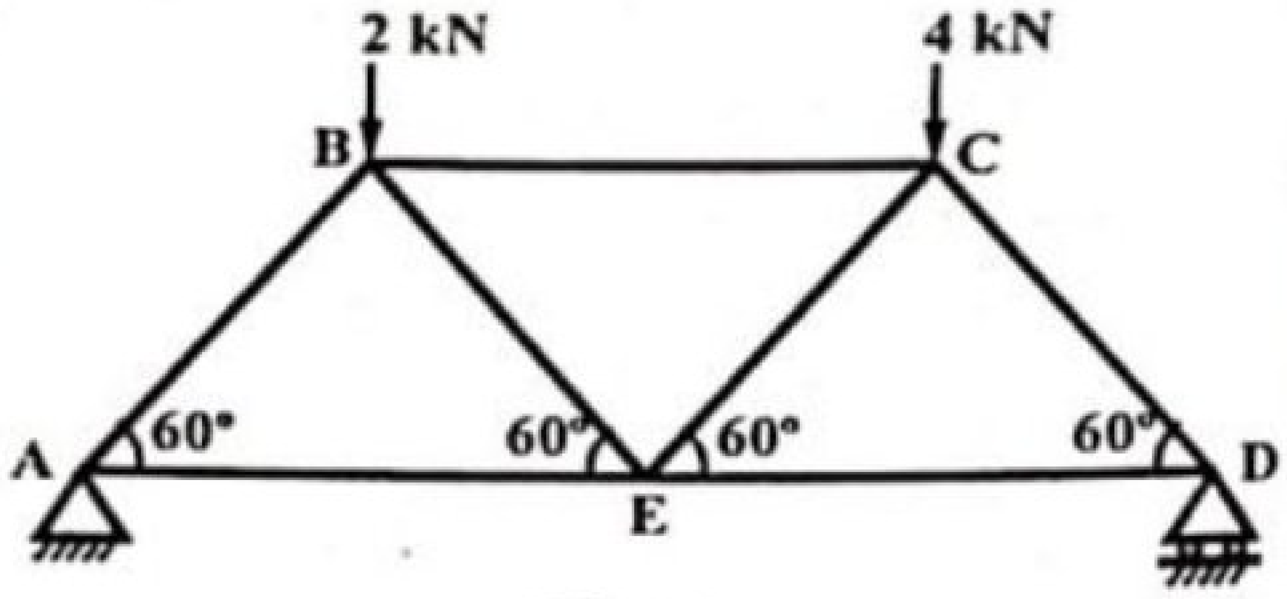


Fig. 1

(See Unit-IV, Page 269, Prob.12)

9. For a circular pipe of 150 mm external diameter and 120 mm internal diameter, determine (i) moment of inertia about its diameter (ii) the radius of gyration and (iii) the polar moment of inertia.

(See Unit-V, Page 328, Prob.12)

Or

10. Draw the shear force and bending moment diagrams for the beams shown in fig. 2.

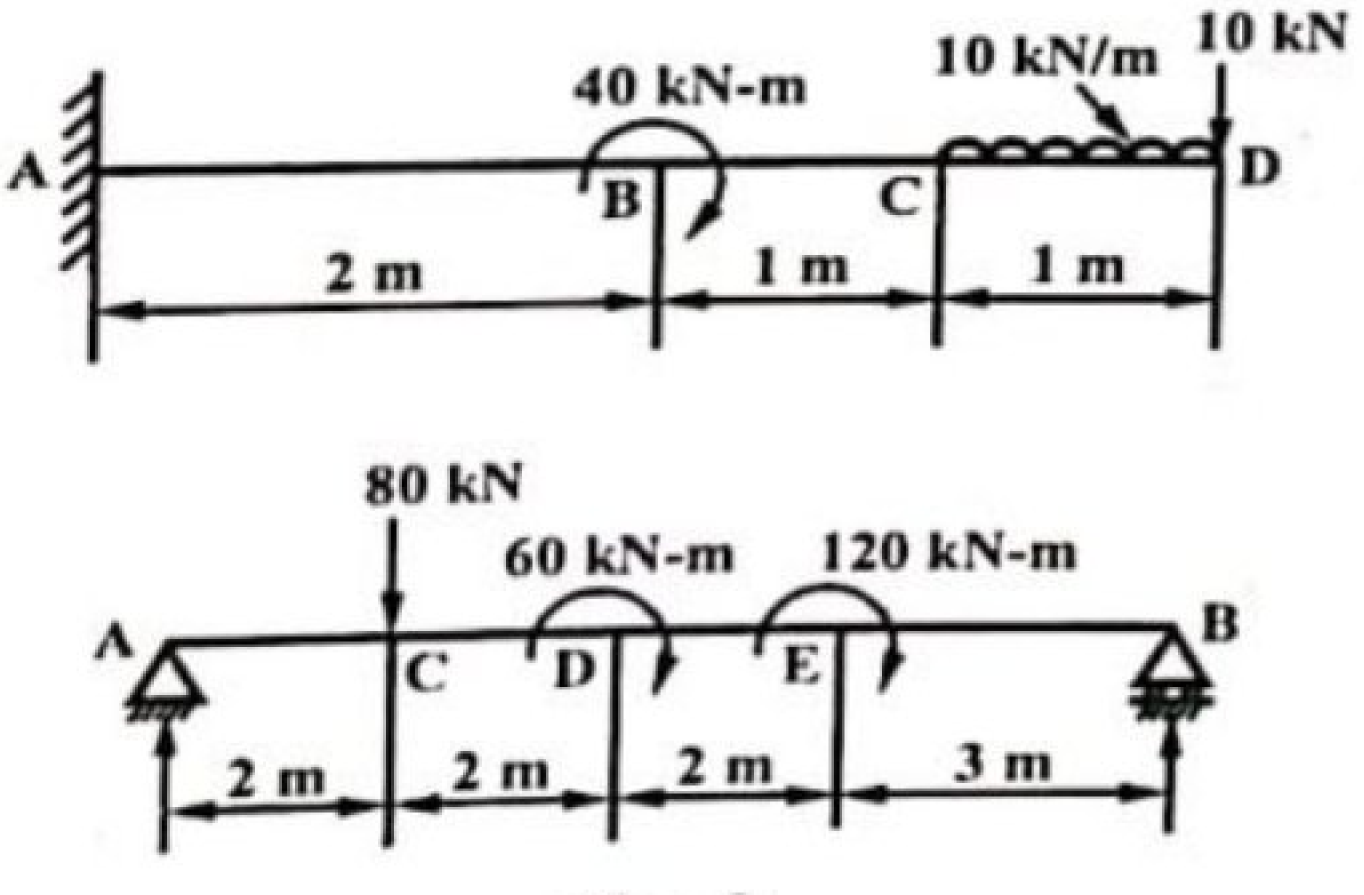


Fig. 2

(See Unit-V, Page 345, 346, Prob.19, 20)

RGPV

B.E. (First/Second Semester)
EXAMINATION, June, 2014
BASIC CIVIL ENGINEERING
& ENGINEERING MECHANICS
(BE-204)

Note : **(i)** Answer five questions. In each question part A, B, C is compulsory and D part has internal choice.

(ii) All parts of each question are to be attempted at one place.

(iii) All questions carry equal marks, out of which part A and B (Max. 50 words) carry 2 marks. part C (Max. 100 words) carry 3 marks, part D (Max. 400 words) carry 7 marks.

(iv) Except numericals, Derivation, Design and Drawing etc.

1. (a) What do you mean by M-30 concrete ? Explain. 2
(See Unit-I, Page 47, Q.64)

(b) Enumerate and describe the tests which may be performed in field to assess the quality of bricks. **(See Unit-I, Page 14, Q.19)** 2

(c) What do you mean by workability of the concrete ? Explain about the various factors affecting it. **(See Unit-I, Page 37, Q.50)** 3

(d) What are the objectives for providing foundation in the building ? Draw a neat sketch of RCC circular column footing with details of column and pedestal. **(See Unit-I, Page 68, Q.88)** 7

Or

Mention the various factors considered while choosing location of stair in a building. Draw neat sketch of Dog-legged stair showing various components of the stair. **(See Unit-I, Page 96, Q.116)** 7

2. (a) What do you mean by transit and non transit theodolite ? 2
(See Unit-II, Page 174, Q.56)

(b) What are the various fundamental lines in a theodolites/level and what is the desired relation amongst them ? 2

(c) Prove that the curvature and refraction errors are eliminated in reciprocal levelling. **(See Unit-II, Page 156, Q.45)** 3

(d) Following consecutive readings were taken on a continuously sloping ground at regular interval of 30 m. Find the gradient joining first and last point (using 5 m reveling staff) 1.370 m, 2.055 m, 2.760 m, 0.455 m, 1.110 m, 1.875 m, 2.57 m, 0.305 m, 0.995 m, 1.685 m. Enter the above readings in a page of field and level book. Deduce RL of intermediate points using H.I. method. 7
(See Unit-II, Page 171, Prob.25)

Or

Explain how plotting can be done by plane table surveying using method of traversing. Mention step by step procedure. 7

(See Unit-II, Page 189, Q.74)

3. (a) Explain the factors on which contour interval depends. 2

(See Unit-III, Page 200, Q.6)

(b) Draw contours of ridge and a valley line assigning suitable values to the contour shown in the figure (in your answer). 2

(See Unit-III, Page 199, Q.3)

(c) Write an explanatory note on applications of remote sensing. 3

(See Unit-III, Page 225, Q.25)

(d) A Rectangular Plot abcd forms the plane of a pit for borrowing Earth from it e is point of intersection of the diagonals. Calculate Volume of excavation using following data. 7

Point.	a	b	c	d	e
Original levels (m)	45.2	49.8	51.2	47.2	52.0
Final levels (m)	38.6	39.8	42.6	40.6	42.5

Provided Length ab = 50 m bc = 80 m

(See Unit-III, Page 224, Prob.9)

Or

Explain How contour maps can be used to draw cross sectioning and to find out capacity of a reservoir. (See Unit-III, Page 202, Q.12) 7

4. (a) State and explain theorem of varignon. 2

(See Unit-IV, Page 238, Q.20)

(b) Show how a force acting on a body can be replaced by an equivalent force couple system. (See Unit-IV, Page 242, Q.26) 2

(c) How determinacy and stability of a frame can be ascertained ? 3

(See Unit-IV, Page 264, Q.43)

(d) Determine axial forces in the members CF, FD, DG, GE and EB of Simply supported loaded truss as shown in fig. 1. 7

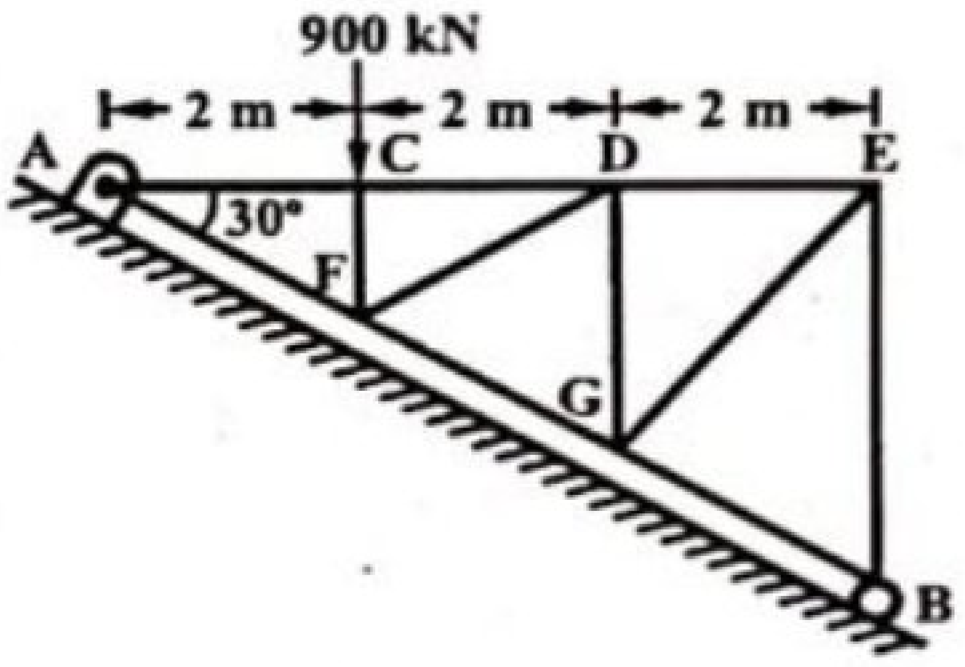


Fig. 1. (See Unit-IV, Page 278, Prob.16)

Or

A Prismatic bar of length 2.1 m and weight 365 N rests within a hemispherical bowl of radius 0.7 m as shown in fig. 2. Determine angle α for position of equilibrium. 7

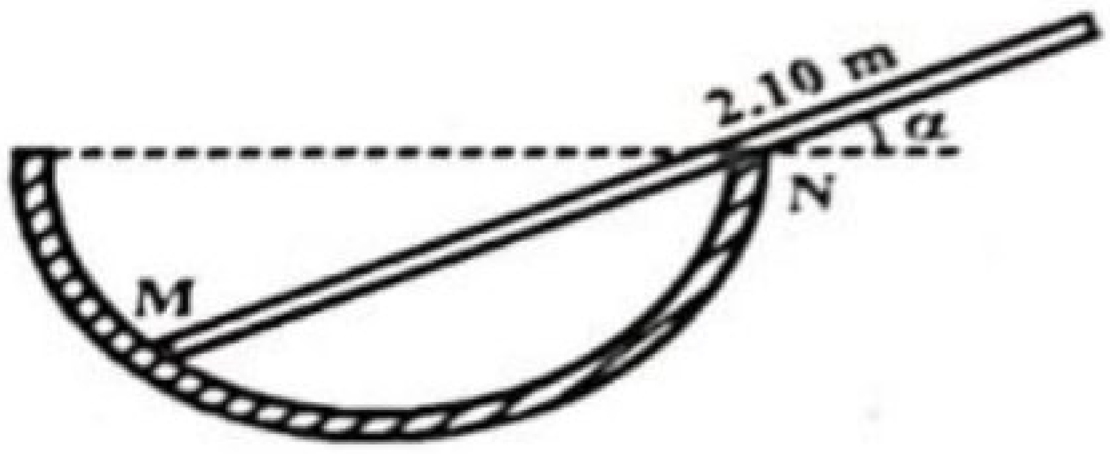


Fig. 2. **(See Unit-IV, Page 245, Prob.4)**

5. **(a)** What do you mean by polar moment of inertia ? 2
(See Unit-V, Page 310, Q.15)

(b) What are the various types of supports of a beam ? 2
(See Unit-V, Page 337, Q.33)

(c) What do you understand by second moment of area and radius of Gyration ? Explain. **(See Unit-V, Page 315, Q.22)** 3

(d) Determine the centroid of the sector of the circle using two different approaches. (Fig. 3). 7

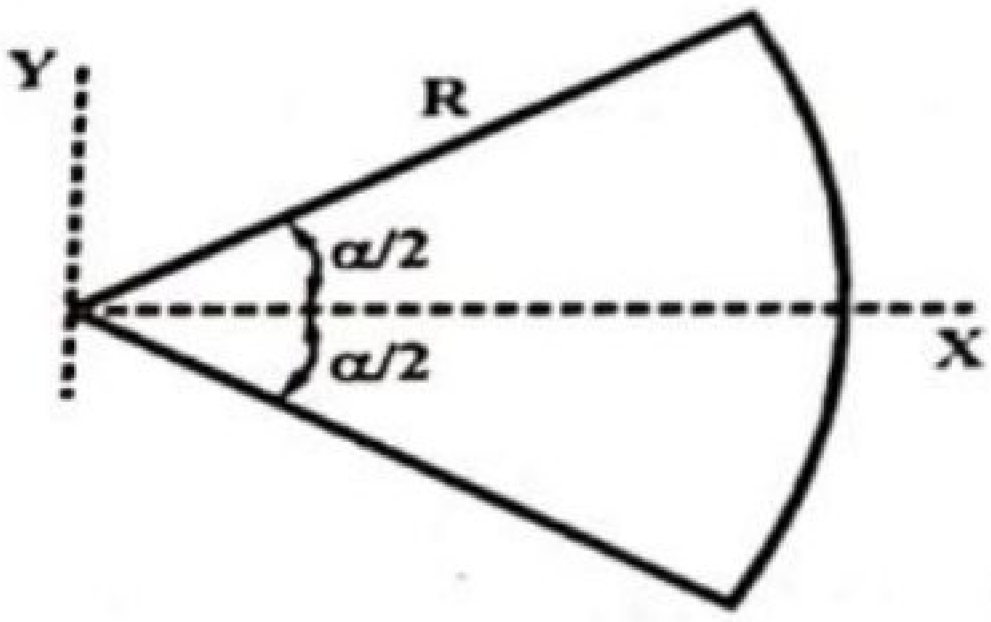


Fig. 3. **(See Unit-V, Page 302, Prob.2)**

Or

Draw the shear force and bending moment diagram for beam as shown in Fig. 4. 7

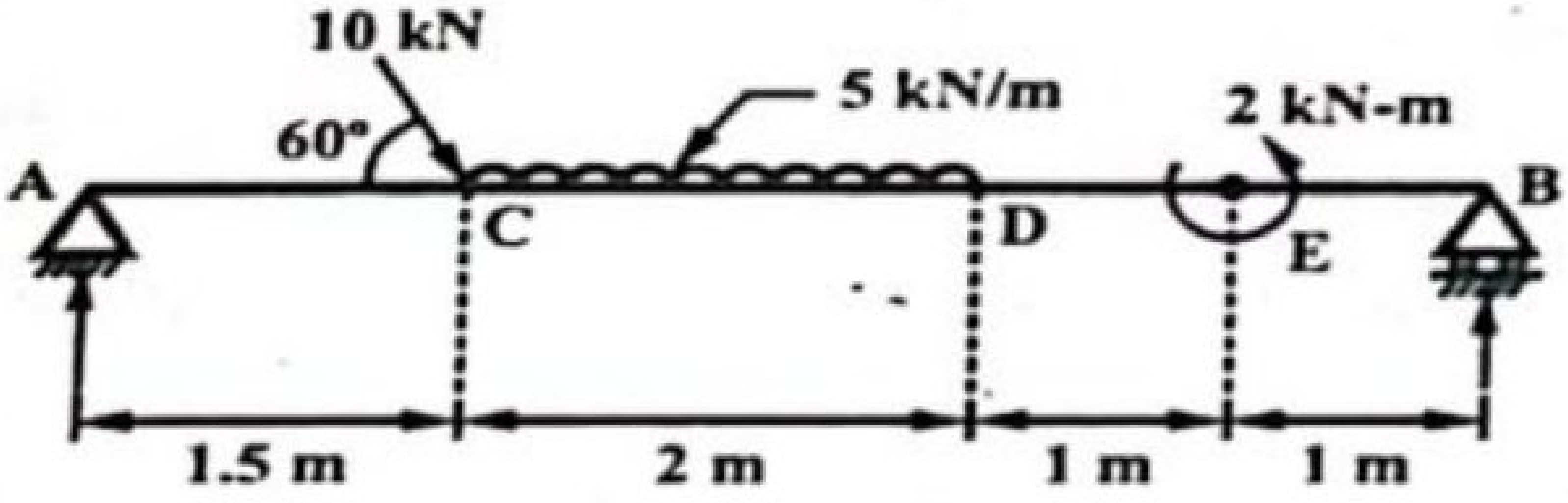


Fig. 4. **(See Unit-V, Page 351, Prob.24)**

RGPV

B.E. (First/Second Semester)
EXAMINATION, Dec., 2014
BASIC CIVIL ENGINEERING & ENGINEERING MECHANICS
(BE-204)

Note : (i) Answer five questions. In each question part A, B, C is compulsory and D part has internal choice.

(ii) All parts of each question are to be attempted at one place.

(iii) All questions carry equal marks, out of which part A and B (Max.
50 words) carry 2 marks. part C (Max. 100 words) carry 3 marks, part D (Max. 400 words) carry 7 marks.

(iv) Except numericals, Derivation, Design and Drawing etc.

Unit-I

1. (a) How workability of concrete can be increased.

(See Unit-I, Page 37, Q.49)

(b) What is white cement ? How is it manufactured.

(See Unit-I, Page 17, Q.27)

(c) What are the various field tests carried out for bricks.

(See Unit-I, Page 14, Q.19)

(d) Describe various defects in timber with help of neat sketches.

(See Unit-I, Page 29, Q.39)

Or

Explain the method of plastering on wall. Also write the advantages of plastering. (See Unit-I, Page 74, Q.93)

Unit-II

2. (a) Stating various types of bench marks, define G.T.S. bench mark.

(See Unit-II, Page 163, Q.51)

(b) State various conventional methods of distance measurement. Write two advantages and two disadvantages of conventional methods of measurement.

(c) What are the advantages and disadvantages of plane table surveying ?

(See Unit-II, Page 183, Q.68)

(d) The following consecutive readings were taken with a level and a 4.0 m staff on a continuously sloping ground at a common interval of 30 m.

0.780, 1.535, 1.955. 2.430, 2.985, 3.480, 1.555, 1.960, 2.265, 3.640, 0.935, 1.045, 1.630 and 2.545.

The reduced level of the first point A was 180.750 m. Rule out a page of level field book and enter the above readings. Calculate the reduced levels of the points by the collimation system. Also calculate the gradient of the line joining the first and the last point.

(See Unit-II, Page 170, Prob.23)

Or

Explain reciprocal levelling in detail. (See Unit-II, Page 156, Q.45)

Unit-III

3. (a) What are the selection criteria of survey station ?
(See Unit-III, Page 218, Q.23)

(b) State various applications of Remote Sensing.
(See Unit-III, Page 225, Q.25)

(c) Explain the graphical method of interpolation of contour with example.
(See Unit-III, Page 209, Q.15)

(d) A road embankment is 8 m wide and 200 m in length at the formation level, with a side slope of 1.5 : 1. The embankment has a rising gradient of 1 in 10 m. The ground levels at every 50 m along the centre line are as follows –

Distance (m)	0	50	100	150	200
R.L.(m)	164.5	165.2	166.8	167	167.2

The formation level of zero chainage is 166 m. Calculate the volume of earth work by using Trapezoidal rule and Prismoidal rule.

(See Unit-III, Page 223, Prob.8)

Or

The area of square of 10 cm side was measured by a planimeter with anchor point out side the figure and the initial and final readings were found to be 6.852 and 8.704 respectively. With the same setting of the tracing arm and the anchor point out side, another irregular figure was traversed clock wise and the initial and final readings were found to be 2.378 and 8.626 respectively. If the plan scale is 1 cm = 10 m. Calculate the area of figure in m^2.

Unit-IV

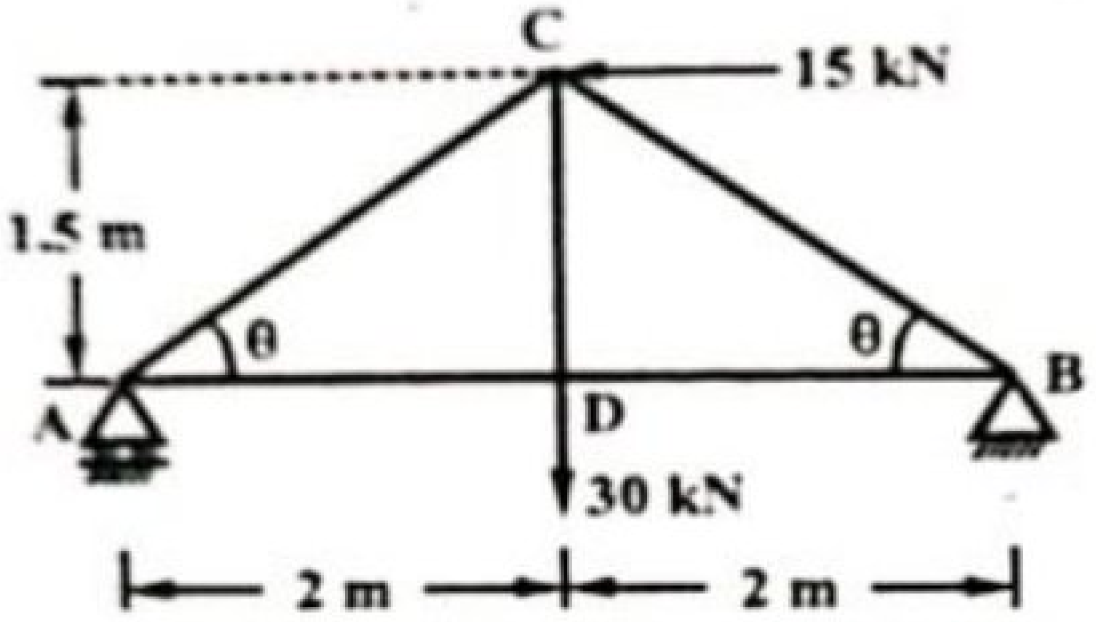
4. (a) What is redundant frame ? (See Unit-IV, Page 264, Q.41)

(b) What are the various types of forces ? (See Unit-IV, Page 230, Q.5)

(c) What are the assumptions made while analysing a frame ?

(See Unit-IV, Page 262, Q.38)

(d) Determine the magnitude and nature of various forces in the various members of the triangular truss loaded and supported as shown in the figure below.



(See Unit-IV, Page 273, Prob.14)

Or

A smooth sphere of radius 15 cm and weight 2 N is supported in contact with a smooth vertical wall by a string whose length equals the radius of sphere. The string joins a point on the wall and a point on the surface of sphere. Workout inclination and the tension in the string and reaction of the wall. (See Unit-IV, Page 252, Prob.5)

Unit-V

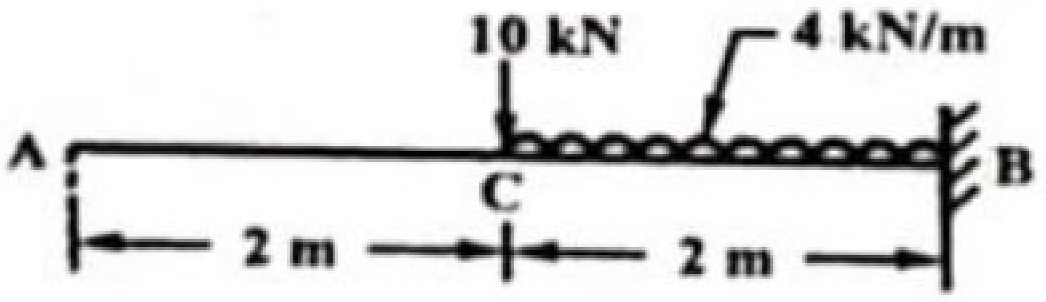
5. (a) What remains the position of centroid/C.G. of following laminas ? (i) Rectangular section (ii) Triangular section (iii) Circular section (iv) Semi circle (v) Hemi sphere (vi) Uniform rod.

(See Unit-V, Page 301, Q.8)

(b) State perpendicular axis theorem. (See Unit-V, Page 309, Q.12)

(c) Defining shear force (S.F.) and Bending moment (B.M.) give the sign conventions for S.I. and B.M. (See Unit-V, Page 338, Q.36)

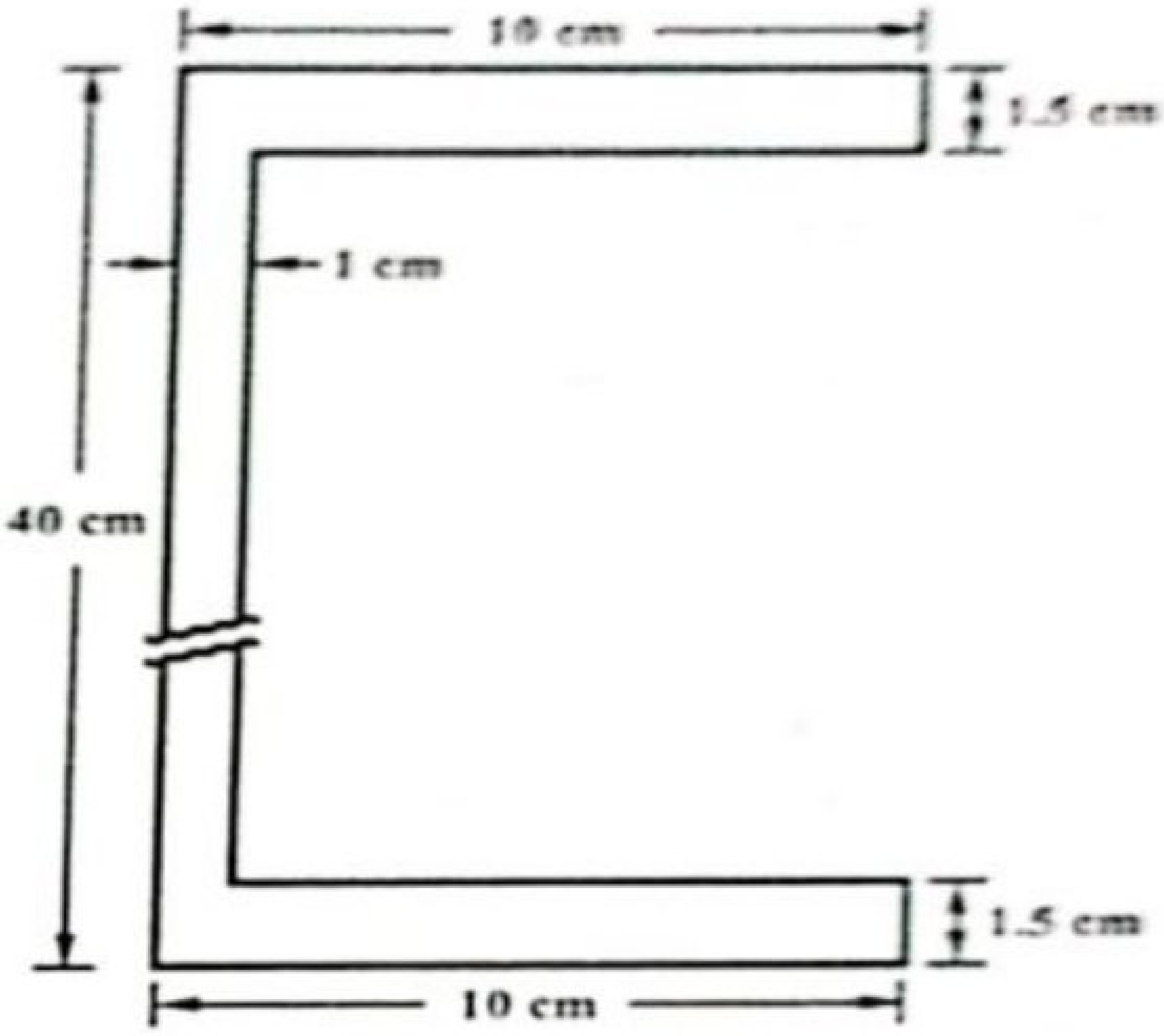
(d) Draw S.I. and B.M. diagram for cantilever beam loaded as shown in figure below. Also locate the position of point of contraflexure.



(See Unit-V, Page 341, Prob.15)

Or

Determine the moment of inertia about centroidal axes x-x and y-y of the channel section as shown in figure below.



(See Unit-V, Page 325, Prob.11)

RGPV

B.E. (First/Second Semester)
EXAMINATION, June 2015
BASIC CIVIL ENGINEERING
& ENGINEERING MECHANICS
(BE-204)

Note : **(i)** Answer five questions. In each question part A, B, C is compulsory and D part has internal choice.

(ii) All parts of each questions are to be attempted at one place.

(iii) All questions carry equal marks, out of which part A and B (Max. 50 words) carry 2 marks, part C (Max. 100 words) carry 3 marks, part D (Max. 400 words) carry 7 marks.

(iv) Except numericals, Derivation, Design and Drawing etc.

1. **(a)** Explain the function of adding gypsum in the manufacture of portland cement.

(b) What are the good qualities of first class bricks ?

(See Unit-I, Page 12, Q.14)

(c) Define cement concrete and mention its properties.

(See Unit-I, Page 36. Q.47)

(d) Explain, with the help of sketches, various types of spread footing.

[See Unit-I, Page 59, Q. 82 (i)]

Or

State the circumstances under which you use the following types of stairs –

(i) Dog legged stair (ii) Spiral stair.

(See Unit-I, Page 95, Q.115)

2. **(a)** What are the main functions of a theodolite ?

(See Unit-II, Page 174, Q.55)

(b) Convert the following W.C.B. into Q.B. –

(i) N 35°10' W (ii) S 88°30' E.

(See Unit-II, Page 140, Prob.7)

(c) Explain the principle of electronic distance measurement.

(See Unit-II, Page 191, Q.76)

(d) The following consecutive reading were taken by a level 0.975, 1.225, 1.465, 1.025, 1.825, 1.355, 0.785, 0.235, 2.135, 1.225, 3.160. The instrument was shifted after fourth and seventh readings. Enter the data in level book and calculate R.L. of all points by any one method if the first reading was taken on B.M. 100.0 m.

(See Unit-II, Page 169, Prob.19)

Or

What is local attraction ? How it is detected and removed ?

(See Unit-II, Page 136, Q.38)

3. **(a)** Define the following terms –

(i) Horizontal equivalent (See Unit-III, Page 202, Q.10)

(ii) Survey station. (See Unit-II.

(b) With reference to civil engineering practice, explain what is meant by the prismoidal rule ? (See Unit-III, Page 217, Q.20)

(c) Show with neat sketches the characteristic features of contour lines for the following –

(i) A ridge (ii) A vertical cliff.

(See Unit-III, Page 199, Q.2)

(d) The following offsets were taken from a chain line to hedge –

Distance (m)	0	20	40	60	80	120	160	220	280
Offset (m)	9.4	10.8	13.6	11.2	9.6	8.4	7.5	6.3	4.6

Compute the area included between the chain line and the offset by
(i) Mid ordinate rule (ii) Simpson's rule.

(See Unit-III, Page 220, Prob.4)

Or

Explain in brief the various methods of measurement of area by offsets from the base line. **(See Unit-III, Page 210, Q.16)**

4. **(a)** What is the difference between collinear and concurrent forces ?

(See Unit-IV, Page 232, Q.7)

(b) State and explain the law of polygon of forces.

(See Unit-IV, Page 235, Q.14)

(c) A body of weight W is resting on a rough inclined plane. Draw free body diagram of the body. Write also equations of equilibrium.

(See Unit-IV, Page 248, Q.30)

(d) Find the forces in the members AB and AC of the truss shown in fig. using method of section.

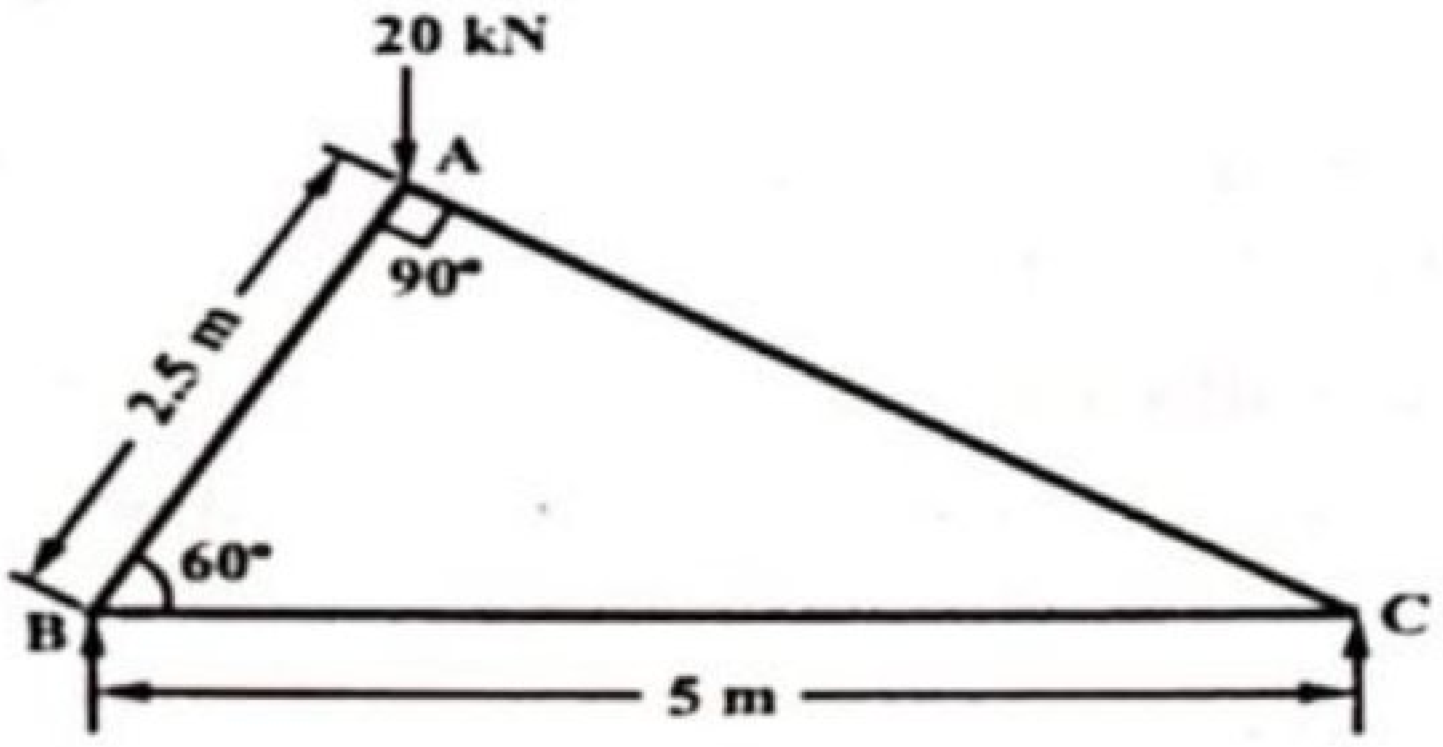


Fig. **(See Unit-IV, Page 280, Prob.17)**

Or

What are the different methods of analysis of a perfect frame ? Which one is used where ? Why ? **(See Unit-IV, Page 265, Q.44)**

5. **(a)** Distinguish between centre of gravity and centroid.

(See Unit-V, Page 297, Q.3)

(b) Explain the following terms –

(i) Principal axes (ii) Radius of gyration.

(See Unit-V, Page 330, Q.26)

(c) Explain the term 'support reaction'. What are the difference types of support ?

(See Unit-V, Page 337, Q.32)

(d) Find the moment of inertia of a hollow section, shown in figure about an axis passing through its C.G. and parallel to X-X axis.

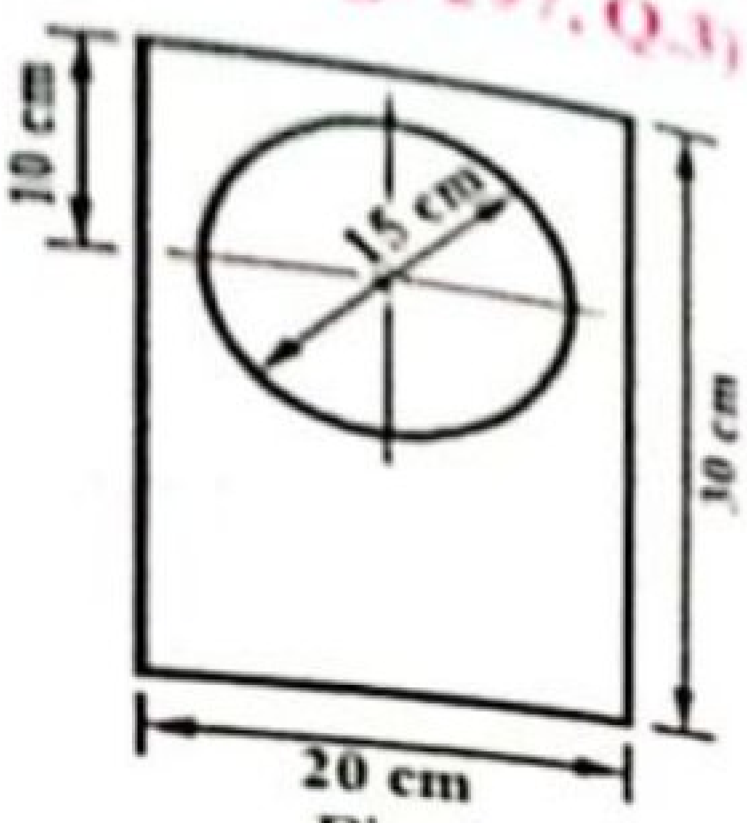


Fig.

(See Unit-V, Page 315, Prob.5)

Or

A beam 5.0 m long and simply supported at each end, has a uniformly distributed load of 1000 N/m extending from the left to a point 2.0 m away. There is also a clockwise couple of 1500 N-m applied at the centre of the beam. Draw the S.F and B.M. diagram for the beam.

(See Unit-V, Page 349, Prob.22)

RGPV

B.E. (First/Second Semester)
EXAMINATION, Dec. 2015
BASIC CIVIL ENGINEERING & ENGINEERING MECHANICS
(BE-204)

Note : (i) Answer five questions. In each question part A, B, C is compulsory and D part has internal choice.

(ii) All parts of each questions are to be attempted at one place.

(iii) All questions carry equal marks, out of which part A and B (Max. 50 words) carry 2 marks, part C (Max. 100 words) carry 3 marks, part D (Max. 400 words) carry 7 marks.

(iv) Except numericals, Derivation, Design and Drawing etc.

1. **(a)** What do you understand by building materials ? Give examples.

(See Unit-I, Page 3, Q.1)

(b) What is the mean of curing ? Also state the principle behind the curing.

(See Unit-I, Page 45, Q.61)

(c) List out various methods of seasoning of Timber.

(See Unit-I, Page 31, Q.41)

(d) What is slump ? Also explain different types of foundation.

(See Unit-I, Page 64, Q.83)

Or

List out various types of doors and windows with suitable sketch.

(See Unit-I, Page 89, Q.106)

2. **(a)** List out of various surveying instruments. Also show their application.

(See Unit-II, Page 115, Q.12)

(b) What is local attraction ? And how it is detected at a station ?

(See Unit-II, Page 136, Q.38)

(c) Define –

(i) Bearing of a line (See Unit-II, Page 129, Q.29)

(ii) Reciprocal leveling. (See Unit-II, Page 157, Q.45)

(d) What is theodolite ? And where is it used ? Also give its full sketch with various parts. (See Unit-II, Page 176, Q.58)

Or

The following readings were observed successively with a level, the instrument having been moved after third, sixth and eighth readings – 2.220, 1.616, 0.978, 2.090, 2.764, 1.622, 0.602, 1.983, 1.045, 2.654 metres.

Enter the above reading in a page of a level book and calculate the R.L. of points if the first reading was taken with a staff held on a bench mark of 400 m. (See Unit-II, Page 168, Prob.18)

3. **(a)** What do you understand by the term "mapping" and "sensing" ?

(b) What is contour and contour interval ? (See Unit-III, Page 201, Q.8)

(c) Briefly discuss the properties of contour. (See Unit-III, Page 200, Q.4)

(d) List out with details of various methods to calculate area and volume in surveying. (See Unit-III, Page 217, Q.19)

Or

What is remote sensing ? Give its application to civil engineering.

(See Unit-III, Page 226, Q.25)

4. **(a)** What are different statically equilibrium conditions ? Explain.

(See Unit-IV, Page 250, Q.35)

(b) Define –

(i) Coplanar forces (ii) Concurrent forces.

(See Unit-IV, Page 232 Q.6)

(c) Define concept of free body diagram. Also show its applications.

(See Unit-IV, Page 247, Q.28)

(d) What are different methods to analysis a plane truss ? Also explain their limitations. (See Unit-IV, Page 266, Q.47)

Or

State and prove Lami's theorem of three forces.

(See Unit-IV, Page 251, Q.36)

5. **(a)** What do you understand by centre of gravity ?

(See Unit-V, Page 297, Q.1)

(b) What is product of inertia ? (See Unit-V, Page 329, Q.24)

(c) Define and explain parallel axis theorem.

(See Unit-V, Page 308, Q.11)

(d) Given a triangular plane lamina as shown in figure in which a small triangular part can be cut at the exact middle of each arm. Calculate moment of inertia about the axis AB of given plane hollow lamina as shown in figure below.

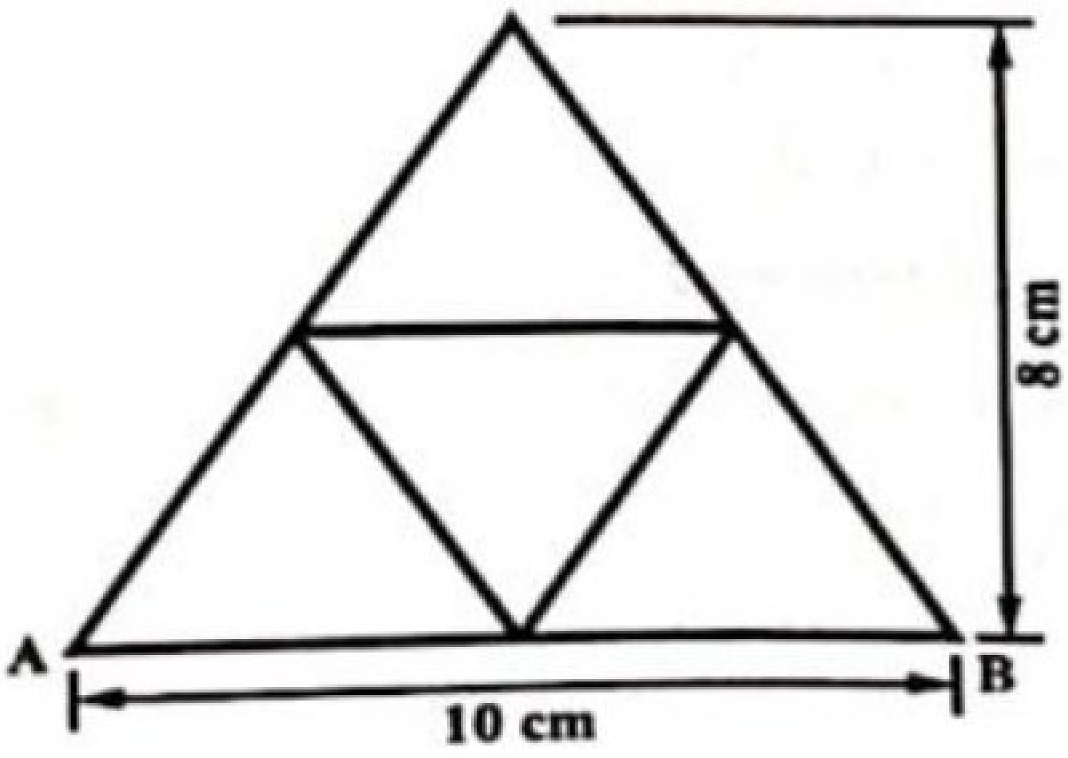


Fig.

(See Unit-V, Page 317, Prob.7)

Or

Deduce an expression for centroidal moment of inertia of X-X and Y-Y axes of a circular plane lamina. (See Unit-V, Page 311, Q.17)

RGPV

B.E. (First/Second Semester)
EXAMINATION, June 2016
BASIC CIVIL ENGINEERING & ENGINEERING MECHANICS
(BE-204)

Note : **(i)** Answer five questions. In each question part A, B, C is compulsory and D part has internal choice.

(ii) All parts of each questions are to be attempted at one place.

(iii) All questions carry equal marks, out of which part A and B (Max. 50 words) carry 2 marks, part C (Max. 100 words) carry 3 marks, part D (Max. 400 words) carry 7 marks.

(iv) Except numericals, Derivation, Design and Drawing etc.

1. **(a)** What do you understand by the term workability ? Explain.

(See Unit-I, Page 37, Q.49)

(b) What is frog ? Explain. (See Unit-I, Page 10, Q.10)

(c) Define –

(i) Curing (See Unit-I, Page 45, Q.61)

(ii) R.C.C. (See Unit-I, Page 50, Q.68)

(d) What are various properties of cement ? Explain in with salient points.

(See Unit-I, Page 17, Q.28)

Or

Define –

(i) Plastering and pointing (See Unit-I, Page 73, Q.92)

(ii) Elements of building construction. (See Unit-I, Page 53, Q.73)

2. **(a)** What do you understand by plane table surveying ?

(See Unit-II, Page 183, Q.67)

(b) What do you understand by the term "EDM" and "Bearing" of a line ?

(See Unit-II, Page 129, 191, Q.29, 75)

(c) What is reciprocal levelling ? Also define reciprocal levelling.

(See Unit-II, Page 157, Q.45)

(d) What are various steps of temporary adjustment of theodolite ? Also explain its uses. **(See Unit-II, Page 178, Q.62)**

Or

The following staff readings were taken with a level which was shifted after 4th, 7th and 10th reading – 2.235, 1.616, 0.960, 2.090, 2.840, 1.622, 1.930, 1.983, 1.045, 2.150, 2.370, 2.654 metres. Assuming the R.L. of starting point as 350.00 m, enter the readings in the form of level book page and calculate the R.L. of points.

(See Unit-II, Page 169, Prob.20)

13. **(a)** What is survey station ? Where this term use ?

(See Unit-II, Page 115, Q.13)

(b) What do you understand by GPS ? **

(c) Enumerates various properties of contour.

(See Unit-III, Page 200, Q.4)

(d) A series of offsets were taken from a chain line to a curved boundary line at intervals of 15 m in the following order – 0.00, 2.60, 3.85, 3.98, 4.12, 4.95, 5.80 metre. Compute the area between the chain line and the curved boundary the end offset by –

(i) Simpson's rule (ii) Trapezoidal rule.

(See Unit-III, Page 219, Prob.2)

Or

Define and describe remote sensing and its various applications in civil engineering. **(See Unit-III, Page 226, Q.25)**

4. **(a)** Define free body diagram. **(See Unit-IV, Page 247, Q.28)**

(b) What do you understand by coplanar and concurrent forces ?

(See Unit-IV, Page 232, Q.6)

(c) What are various limitations of method of joint and method of section ?

(See Unit-IV, Page 266, Q.48)

(d) State and prove Lami's theorem of three forces.

(See Unit-IV, Page 251, Q.36)

Or

Analyze the truss shown below in fig. 1.0. All the members are of equal length of 4 m.

****Now, according to new revised syllabus of R.G.P.V., it is not included in syllabus**

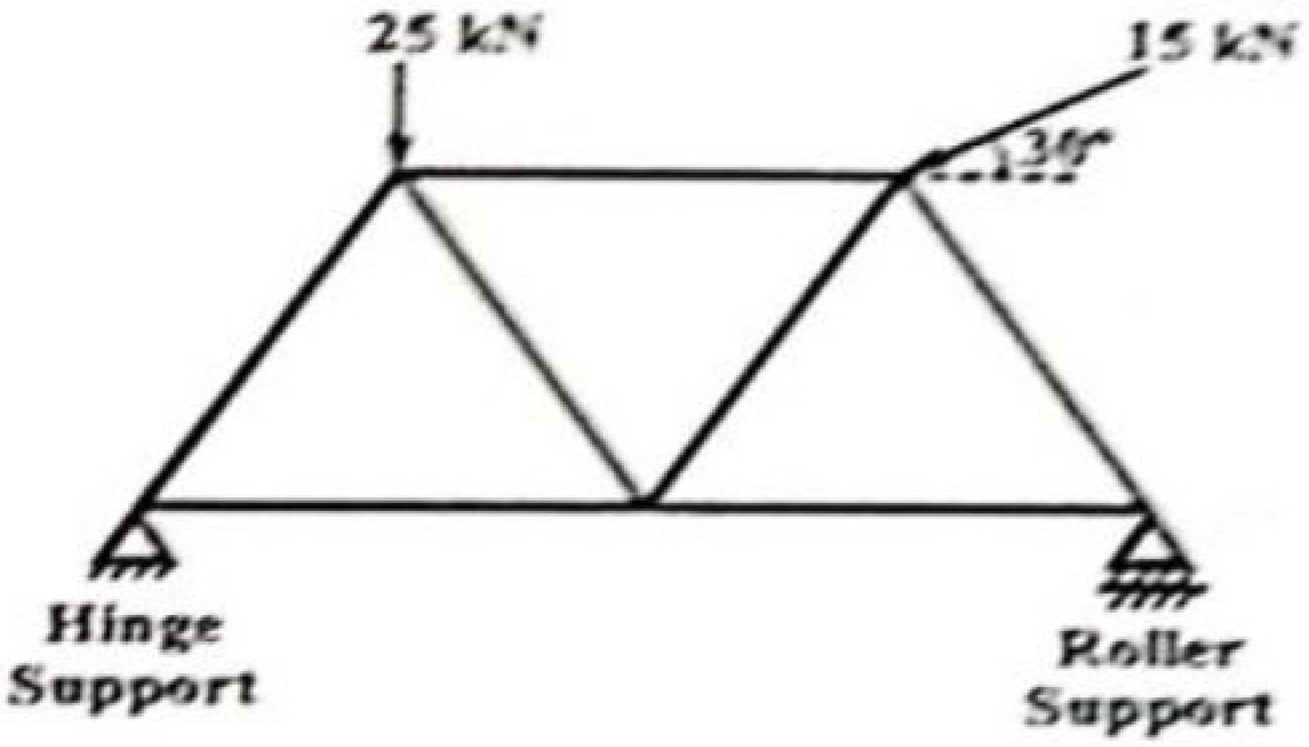


Fig. 1.0

(See Unit-IV, Page 271, Prob.13)

5. **(a)** What is shear force and bending moment ?

(See Unit-V, Page 337, Q.34)

(b) Define radius of gyration and its uses. (See Unit-V, Page 314, Q.21)

(c) Enumerate the expression for perpendicular axis theorem.

(See Unit-V, Page 309, Q.13)

(d) Draw shear force and bending moment diagram for a cantilever beam loaded as shown in fig. 2.0 below.

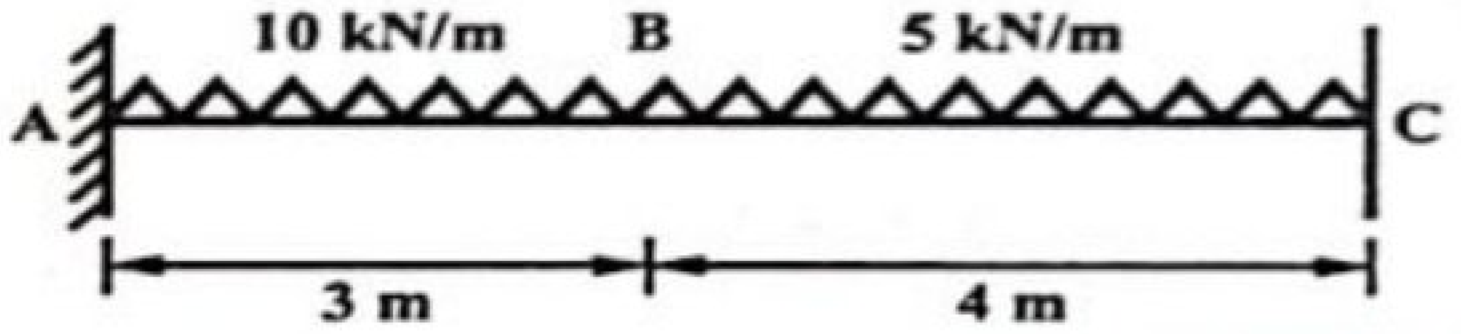


Fig. 2.0 (See Unit-V, Page 341, Prob.16)

Or

Enumerate the expression for a moment of inertia of triangular lamina about its base. (See Unit-V, Page 313, Q.19)

RGPV

B.E. (First/Second Semester)
EXAMINATION, Dec. 2016
BASIC CIVIL ENGINEERING & ENGINEERING MECHANICS
(BE-204)

Note : (i) Answer any five questions.

(ii) All questions carry equal marks.

(iii) Assume suitable data if necessary.

1. (a) Explain the different types of cement. **(See Unit-I, Page 16, Q.26)**
   (b) Explain briefly the factors that affect the workability of concrete. **(See Unit-I, Page 38, Q.51)**

2. (a) Explain various types of foundations. **(See Unit-I, Page 59, Q.82)**
   (b) Explain the seasoning of timber. **(See Unit-I, Page 31, Q.41)**

3. (a) Draw a neat sketch of door and window and explain its components. **(See Unit-I, Page 89, Q.107)**
   (b) Explain various types of test that can be conducted on bricks. **(See Unit-I, Page 15, Q.22)**

4. (a) Explain different types of theodolite. **(See Unit-II, Page 174, Q.56)**
   (b) Explain reciprocal levelling. **(See Unit-II, Page 156, Q.45)**

5. (a) Explain survey station and its importance. **(See Unit-II, Page 115, Q.13)**
   (b) Explain the importance of remote sensing in civil engineering. **(See Unit-III, Page 228, Q.26)**

6. (a) Explain the method of joints. **(See Unit-IV, Page 265, Q.45)**
   (b) What do you mean by free diagram and force diagram ? **(See Unit-IV, Page 248, Q.31)**

7. (a) Explain radius of gyration of any section with a neat sketch. **(See Unit-V, Page 314, Q.21)**
   (b) What do you mean by support reaction, explain shear force and bending moment ? **(See Unit-V, Page 338, Q.35)**

8. Write short notes on (any three) –
   (a) Couple **(See Unit-IV, Page 241, Q.24)**
   (b) EDM method **(See Unit-II, Page 193, Q.78)**
   (c) Contour interval **(See Unit-III, Page 202, Q.9)**
   (d) Plastering **(See Unit-I, Page 73, Q.92)**
   (e) Pointing. **(See Unit-II, Page 73, Q.92)**

RGPV

BT-2004 (CBGS)
B.Tech., First Semester,
EXAMINATION, Dec. 2017
Choice Based Grading System (CBGS)
BASIC CIVIL ENGINEERING & ENGINEERING MECHANICS

Note : (i) Answer any five questions.

(ii) All questions carry equal marks.

(iii) Assume suitable data if missing or necessary.

(iv) In case of any doubt or dispute the English version question should be treated as final.

1. What do you understand by the term "Trusses" ? Also explain various methods to analyses a truss with their advantages and disadvantages.

(See Unit-IV, Page 267, Q.49)

2. Calculate the Moment of Inertia of hollow rectangular section, in which a triangular section cut from a rectangular section (fig. 1.0). Determine Moment of Inertia about A-B axis which is base of the section.

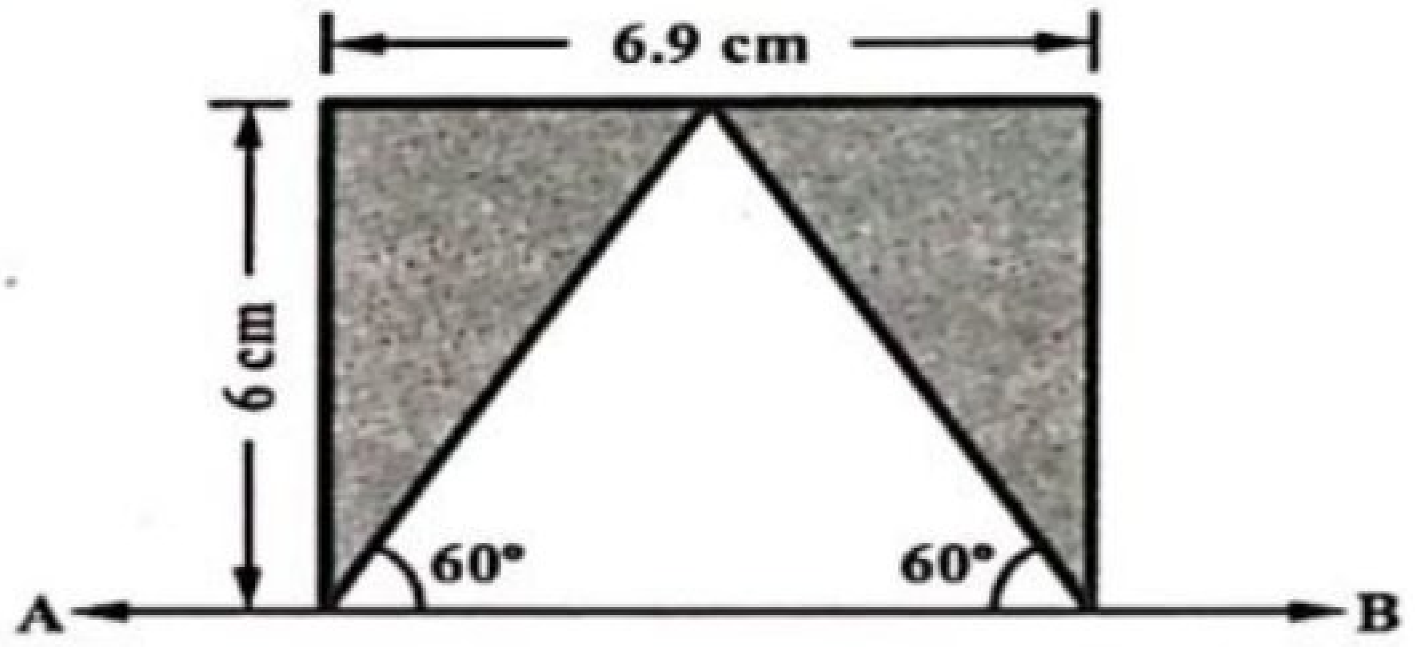


Fig. 1.0 (See Unit-V, Page 316, Prob.6)

3. What are the various Laws of Machines ? **

Explain Principle Axes and Principle Moment of Inertia.

(See Unit-V, Page 331, Q.28)

4. List out various field test and laboratory tests of Cement. Explain any two tests in details. (See Unit-I, Page 24, Q.30)

5. What do you understand by the term "Contour" ? Also show the properties of contours. (See Unit-III, Page 197, Q.3)

6. What do you understand by the term "Workability of concrete" ? Define and explain how we can detect workability. (See Unit-I, Page 49, Q.66)

7. Define and explain various engineering properties of good bricks.

(See Unit-I, Page 12, Q.14)

8. Write short notes on any four of the following –

(a) Local attraction (See Unit-II, Page 136, Q.38)

(b) Bowditch's rule (See Unit-II, Page 128, Q.27)

****Now, according to new revised syllabus of R.G.P.V., it is not included in syllabus**

(c) Lami's theorem **(See Unit-IV, Page 251, Q.36)**

(d) Fore bearing and back bearing of a line **(See Unit-II, Page 132, Q.33)**

(e) Efflorescence. **(See Unit-I, Page 14, Q.17)**

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